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THE IMPACT OF WINGSHIPS ON STRATEGIC LIFT

by

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Operation Desert Shield highlighted tremendous problems with our nation's ability to efficiently move our army and equipment to distant theaters. The wingship, a hybrid air/surface craft is a potential solution to our long-standing sealift deficit. The Sealift Parametric Analysis Model, a simulation provided by the Naval Surface Warfare Center, was modified to adapt wingships so that the vessel's impact on force closure could be analyzed. For a notional force requiring 19 million square feet of combat gear and support equipment, wingships augmenting conventional sealift assets can move the needed equipment into the South Korea or Persia Gulf theater much faster than is currently possible. Even with the large amount of additional square footage of cargo-carrying capability programmed for further sealift assets, troops can be deployed and supported much more quickly with wingships. Given the diverse global threat in this rapidly changing world, wingships provide a strategic deterrent of tremendous value to our nation and to our allies.

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THE IMPACT OF WINGSHIPS ON STRATEGIC LIFT

by

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ABSTRACT

Operation Desert Shield highlighted tremendous problems with our nation's ability to efficiently move our army and equipment to distant theaters. The wingship, a hybrid air/surface craft is a potential solution to our long-standing sealift deficit. The Sealift Parametric Analysis Model, a simulation provided by the Naval Surface Warfare Center, was modified to adapt wingships so that the vessel's impact on force closure could be analyzed. For a notional force requiring 19 million square feet of combat gear and support equipment, wingships augmenting conventional sealift assets can move the needed equipment into the South Korea or Persian Gulf theaters much faster than is currently possible. Even with the large amount of additional square footage of cargo-carrying capability already programmed for further sealift assets, troops can be deployed and supported much more quickly with wingships. Given the diverse global threat in this rapidly changing world, wingships provide a strategic deterrent of tremendous value to our nation and to our allies.

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EXECUTIVE SUMMARY

Operation Desert Shield highlighted significant problems with our nation's ability to efficiently transport our army and equipment to distant theaters. The wingship, a means of high-speed ocean transport, exploits the phenomenon of ground-effect to efficiently move large loads at 400 knots. The hybrid air/sea craft operate in the displacement, or sea-sitting, mode to maneuver into or out of port. The majority of the time, the vessel flies close to the surface of the water in ground-effect.

The Russians have built and operated wingships since the 1970's. Ten protoypes, each one larger than its predecessor, were built and successfully flown. Now, in a joint venture with the United States, the Russians are helping design a much larger wingship. The proposed wingship, designed by Aerocon of Arlington, Virginia, can transport a 1500-ton payload ten thousand nautical miles. Possible payload options include 20 main battle tanks, 60 standard containers, or 30 attack helicopters.

The Sealift Parametric Analysis Model (SPAM), a simulation model provided by the Naval Surface Warfare Center, was modified to incorporate this new asset. Because of peculiarities with wingship operations and the great speed of the vessel, delay times in the event-stepped simulation were

changed to reflect the expected operational delays for this hybrid craft.

Wingship inventories of 10, 20, 30 and 40 vessels were analyzed. The square footage of cargo delivered by the wingships was combined with the output for conventional sealift forces to determine how much more quickly combat and support gear could be moved into theater. A notional deployment force including five army divisions and three marine expeditionary brigades was used to determine a target lift requirement. Deployment to the Persian Gulf and South Korea, two of the most trying scenarios currently envisioned by the Pentagon, were the basis for the analysis.

Wingships can drastically improve the rate of force closure. For the South Korea and Persian Gulf scenarios, a fleet of forty wingships augmenting current lift assets significantly increases the rate of force build-up. In both theaters, the notional force is fully armed and ready to fight in approximately four weeks. This deadline is considerably sooner than is possible with current lift assets. Force closure for conflict in the Persian Gulf is realized 70 days earlier with wingships. The sealift force augmented with 40 wingships delivers cargo to South Korea 74 days sooner than is currently possible.

Sensitivity analysis was performed on the lift requirement, berth space at the port of debarcation, vessel activation times, and wingship stow factor to determine the

force closure under various conditions. In all cases studied, the benefit of having wingships was significant.

Wingships deliver gear earlier and at a higher rate than is possible with conventional lift assets. The value of this quick movement of equipment into theater cannot be overstated. Wingships give theater Commanders in Chief greater flexibility and defensive options until substantial amounts of equipment arrive in theater. Given the diverse global threat in this rapidly changing world, wingships provide a strategic deterrent of tremendous value to our nation and to our allies.

I. INTRODUCTION

The current military strategy of the United States requires the capability to rapidly deploy sizeable forces to all corners of the world. The wingship, a means of high-speed ocean transport, is a hybrid air/sea craft capable of very heavy lift over extremely long ranges. The vessel combines the best features of both sealift and airlift; loads much larger than those carried on board existing cargo aircraft may be moved at a speed of 400 knots. The wingship will complement current strategic lift assets and can be used to bridge the strategic lift gap between the commencement of hostilities and the arrival of gear on Maritime Prepositioning Ships (MPS) and Fast Sealift Support Ships (FSS). The vehicle is also ideally suited for delivery of time critical parts and equipment even after supply channels are well established.

A. WINGSHIP BACKGROUND

Wingships are neither hydrofoils nor Surface Effect Ships (SES). By employing a different lift mechanism, wingships are able to achieve speeds much higher than those attainable with hydrofoil or SES technology. Wingships rapidly move heavy equipment tremendous distances by exploiting the phenomenon of wing-in-ground effect. Flying just above the surface of the water on the cushion of dense air between the water and the vehicle, wingships travel at speeds comparable to transport

aircraft but have the cargo-carrying capability of a small ship [Ref. 1:p. 82].

The Russians have built and successfully operated wingship vehicles since the 1970's. Ten experimental craft were constructed by the Russians, and each wingship was slightly larger in size and mass than its predecessor. The "Caspian Sea Monster" had a gross weight of 550 tons and flew at nearly 300 knots.[Ref. 2:p. 3] Since the demise of the former Soviet Union, the Russians lack the funding to support continued research in this field. Russian experts are now working jointly with the United States to develop a large-scale wingship vehicle.

Congress recently appropriated five million dollars to conduct a feasibility study on the employment of wingship vehicles. Advanced Research Projects Agency (ARPA) assembled a team of thirteen systems and technology experts from various fields to provide an assessment to the Department of Defense (DoD). The results of the preliminary study will determine if further funding will be provided to research this mode of high-speed ocean transport.

The wingship currently under analysis by ARPA is much larger than any of the Russian prototypes. The proposed vehicle has the capability to transport personnel and cargo weighing a total of 1500 tons. Payload options include 20 main battle tanks, 32 attack helicopters, 60 standard containers, or 2000 troops and a 1200 ton mix of equipment and

supplies.[Ref. 3] With an unrefueled range of 10,000 nautical miles at a cruising speed of 400 knots, the wingship can drastically improve force closure. "The wingship will be able to transport ten times the payload of a C-5 or C-17 over twice the distance yet at their same speed."[Ref. 3]

The sweeping political changes throughout the world have reshaped global strategy. "Where deterrence had previously been expressed in megatons of deliverable nuclear explosive power, future deterrence will be expressed in millions of tons of deliverable conventional forces." [Ref. 4:p. [illegible]6] The wingship is the ideal platform to deter aggressors from hostile action against our nation or its allies.

B. OBJECTIVE

With a more geographically diverse military threat to the U.S. and with decreasing forward-deployed assets, the wingship provides necessary flexibility for the deployment of troops and equipment. Additionally, this craft is well suited for various other missions outlined in the National Military Strategy including disaster relief and evacuations of personnel. The goal of this thesis is to determine the optimal number of these aircraft to best meet strategic lift requirements.

C. METHODOLOGY

A modified version of The Sealift Parametric Analysis Model (SPAM) provided by the Naval Surface Weapons Center

(NSWC) is used to assess the impact of wingships on strategic lift. Input files for the simulation include conventional sealift assets and wingships. The model inputs vary so the effect on force closure of various combinations of sealift assets can be studied. Conflict in Korea or Southwest Asia, the most trying scenarios currently envisioned by the Pentagon, are the basis for the model runs.

II. STRATEGIC LIFT IN OPERATION DESERT SHIELD

A. BACKGROUND

Conflict in Southwest Asia had long been considered the most difficult scenario for the United States to fight. Engaging a large, well-equipped force over 8000 miles from home necessitated a massive logistics effort that severely tasked the nation's airlift and sealift forces. When Saddam Hussein moved into Kuwait, the President responded by ordering the largest U.S. deployment since the Vietnam War. Tremendous amounts of cargo and equipment were rapidly moved into the theater; the delivery rate of goods to the Persian Gulf was 33 percent higher than that during the first year of the Korean War [Ref. 5:p. 1].

The victory over Saddam Hussein in Operation Desert Shield was indeed impressive, but a careful look at strategic mobility revealed considerable shortcomings. Had Saddam Hussein not allowed the allies five months to establish logistics channels and build up supplies, the course of the Persian Gulf War may have been quite different.

Shortfalls with strategic sealift were by no means a surprise. In fact, the capability to transport troops and equipment to distant theaters has been considered inadequate since the early 1960's when President Kennedy and his

Secretary of Defense recognized the need for rapid improvements [Ref. 6:p. 345]. Enhancements to strategic lift have been made, but efforts to rectify the lack of adequate lift have been half-hearted at best. Programs to improve strategic lift are often costly and traditionally receive less funding than other high visible national defense programs.

In the decade prior to the Persian Gulf War. four major studies were conducted by DoD to determine sealift requirements. All four of the studies concluded that insufficient strategic lift was available to meet the demands of the most probable deployment scenarios. [Ref. 7:p. 3]

In testimony before the House Merchant Marine Subcommittee in March 1990, Admiral Frank Donovan, Commander, Military Sealift Command (MSC), estimated that augmented MSC peacetime assets could move approximately 80 percent of the surge goal for unit equipment [Ref. 8:p. 45]. Even this estimate about sealift capability was overly optimistic.

B. STRATEGIC SEALIFT FORCE ASSETS

The major components of the strategic sealift force are the Afloat Prepositioning Force (APF), Fast Sealift Support Ships (FSS), the Ready Reserve Force (RRF), and U.S.-flag and foreign-flag dry cargo ships and tankers.

The APF is further divided into Maritime Prepositioning Ships (MPS) and Prepositioning ships (PREPO ships). The thirteen MPSs, each loaded and fully manned, are divided into

three squadrons. Each squadron, under the command of a U.S. Navy captain, carries the supplies and equipment to sustain a Marine Expeditionary Brigade for 30 days of combat [Ref. 9:p. 13]. The squadrons, based on Diego Garcia, Guam and on the east coast of the United States, are active units. The vessels operate regularly and should be able to sail immediately if a crisis erupts. After offloading their initial cargo, these vessels revert to common-user status. The nominal speed of an MPS is fifteen knots. [Ref. 5:p. 10]

The twelve PREPO ships, eight dry cargo ships and four tankers, are loaded with Army, Air Force and Navy equipment. One of these vessels is prepositioned in the Mediterranean; the remainder operate out of Diego Garcia. PREPO ships are always fully manned and should be ready to sail immediately if directed. These vessels cruise between 16 and 20 knots. [Ref. 5:p. 11]

The FSSs are a fleet of eight container ships converted by the Navy to a Roll-On/Roll-Off (RO/RO) configuration. These ships are berthed at CONUS ports and are maintained in a Reduced Operating Status (ROS) with skeleton crews aboard. FSSs should be ready to sail within four days of notification. With nominal cruising speeds of 30 knots, these vessels are by far the fastest means to currently move military equipment and supplies by sea. The combined lift of the FSSs is adequate to move the entire unit equipment of an Army division. [Ref. 5:p. 11]

The RRF, established in 1976 to provide a rapidly deployable force capable of meeting surge sealift needs, is a fleet of former commercial ships purchased because of their military utility. At the start of the Persian Gulf War, the RRF fleet comprised 96 vessels, including 17 RO/ROs, 51 breakbulk carriers, 11 tankers and two troopships. RO/ROs are currently maintained in a ROS condition; the remaining assets are kept in an inactive 5-day, 10-day or 20-day readiness condition. If needed, the inactive RRF assets must be towed to a shipyard for manning and activation. The cruising speed of each of these vessels varies due to vintage and plant configuration.

MSC charters U.S. and foreign-flagged ships to meet sealift shortfalls. These ships can quickly augment sealift assets since they are already fully manned and underway. RO/RO ships, short in the U.S. inventory, are prime candidates for foreign charter.

C. SEALIFT PERFORMANCE DURING DESERT SHIELD

Desert Shield, supported by the largest and most concentrated military sealift operation since World War II, highlighted significant problems with the responsiveness of surge sealift assets. Huge amounts of supplies and equipment were moved to the Persian Gulf, but rapid outfitting of combat troops already in theater was delayed because of the inability of vessels to be readied within programmed guidelines. The

APF and the FSSs responded much as expected and fairly well validated these costly programs. The performance of the RRF, on the other hand, was woefully unsatisfactory.

When Desert Shield commenced, the MPS based on Diego Garcia and Guam were ordered to sail immediately. Ships based on Diego Garcia arrived in Saudi Arabia as early as C+8; those stationed at Guam began arriving to offload gear on C+18. The remaining MPS assets were activated in Phase II of the buildup and arrived in theater 28 days after notification to sail. [Ref. 5:p. 27]

The delivery of equipment on MPS assets was timely, but the loadout contained insufficient quantities of many important items and many items not needed at all. According to a Government Accounting Office report, of the 18,000 line items aboard one squadron, just 800 matched needs in the Gulf War. Conversely, multiple requisitions were received for over 3,000 line items not currently included in the MPF inventory. One Marine division supply officer claimed that over 90 percent of all requisitions processed in theater were for 10 percent of items stocked aboard MPF ships. [Ref. 10:pp. 25-26]

PREPO assets were also dependable surge sealift assets. The eight dry cargo ships were activated on C+2 and arrived for offloading between C+10 and C+14. Five of these ships made subsequent deliveries after reverting to common-user status. [Ref. 5:p. 27]

The workhorses of the surge effort were the eight FSSs. All eight FSSs were ordered to be activated on C-day or C+1. The first ship to be activated loaded with 24,000 tons of equipment, sailed for the Persian Gulf on C+6, and arrived for offload on C+20. By C+31, seven of the eight ships arrived in Saudi Arabia. One vessel sustained a series of boiler casualties and had to be towed to Rota, Spain. Another FSS picked up the cargo in Rota after delivering her own load and delivered it to Saudi Arabia on C+47. The breakdown of the FSS delayed the first wave of deliveries by 16 days. [Ref. 5:p. 28]

Given the maximum speed of the FSSs and the planned assembly, loading and offloading times, cargo aboard these craft should have been delivered to the Persian Gulf by C+21. Delays through the Suez Canal, draft and trim problems associated with improper loading, engineering casualties, and weather all reduced the cruising speed of the FSSs. The first wave of FSSs averaged just over 23 knots -- well below maximum speed. [Ref. 7:p. 8] Even at this speed, the FSSs made a tremendous impact on the buildup effort. During Operation Desert Shield, the FSSs made a total of 31 deliveries to the Gulf, an average of over four deliveries per operating ship [Ref. 5:p. 28].

As mentioned above, the performance of the RRF was abysmal. The readiness conditions of the ships did not reflect the importance of the vessels or the material

condition of the craft. Of the 44 vessels slated for activation during Phase I of the operation, only 27 percent were activated on time. Close to one-half of the ships were activated more than five days late [Ref. 11:p. 6-4]. Even the 17 RO/RO vessels, so vital for the rapid movement of military vehicles, were slow to steam. Just three of these specialized ships were activated within five days. The activation record of the RRF vessels used for surge support is shown in Table I. Figure 1, a scatter plot of activation times for the RRF-5 vessels, further emphasizes the slow response of this vital sealift asset. Activation times for vessels activated during the surge phase of the war range from four to 131 days with an average of 17.11 days. With the three longest activation

TABLE I
RRF ACTIVATIONS FOR SURGE SUPPORT

	5 DAY	10 DAY	20 DAY	TOTAL
EARLY OR ON TIME	8	3	1	12
0-5 DAYS LATE	10	2	0	12
6-20 DAYS LATE	15	1	0	16
> 20 DAYS LATE	4	0	0	4
TOTAL	37	6	1	44

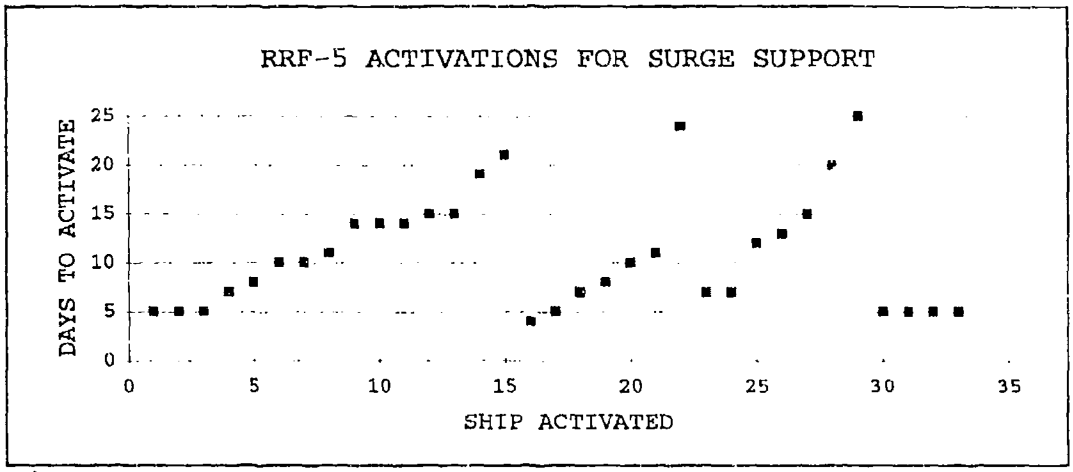

Figure 1. RRF-5 Activation Times

times removed from the data, the mean time drops to 10.94 days--still twice as long as planned.

During Phase II of the buildup, the responsiveness of the RRF was much the same. Just 22 percent of the vessels activated during the follow-on stage of the buildup were loaded on time [Ref. 11:p. 6-4]. In almost every case, the activation delays were the result of the poor material condition of the propulsion or auxiliary machinery. Manning the vessels with qualified merchant mariners also delayed activations.

The performance of the RRF was indeed distressing. In an interview with *Inside the Navy*, Vice Admiral Paul Butcher, then Deputy Commander of Transportation Command (TRANSCOM), remarked

> If people go around saying we did great during Operation Desert Shield, I say the people did great with the assets we had, but don't let that mask the problem...The Ready Reserve Force is predicated on the principle that we would break out the ships all at

> one time...If we had to break out all of the ships simultaneously, we would not have been successful. [Ref. 12:p. 4]

The U.S. and foreign commercial fleets were immediately called upon to augment sealift assets. One hundred and ninety-one ships were chartered to carry unit equipment. Of the total, only 29 were U.S. controlled. The U.S. controlled ships delivered less than 30 percent of the total amount of unit equipment delivered. There were four basic reasons for using charters so extensively: 1)the inventory of RO/ROs in the RRF was inadequate; 2)the response time of the RRF assets was unsatisfactory; 3)manning the RRF vessels was becoming increasingly difficult; and 4)the per diem cost to operate the charters was cheaper than activating and operating the old RRF ships. [Ref. 5:pp. 30-31]

D. ENHANCEMENTS TO STRATEGIC LIFT

The recently completed Mobility Requirements Study (MRS) acknowledged the sealift deficit and proposed a program for the acquisition of additional sealift vessels. Each of the nine vessels added to the PREPO fleet are RO/ROs with a 300,000 square foot capacity. The new FSSs are Large Medium Speed RO/ROs (LMSRs) with a capacity of 380,000 square feet and a cruising speed of 24 knots. The notional delivery profile of the new sealift vessels is shown in Table II. [Ref. 13]

TABLE II
FUTURE ASSETS

	FY 94	FY 96	FY 97	FY 98	TOTAL
PREPO	4	4	1		9
FSS		2	5	4	11
CONTAINER	2				2

The RRF has also been upgraded. Twelve additional RO/ROs have been added to the fleet since Operation Desert Storm and seven more are scheduled for delivery. Maintenance and operation practices have also been revised to improve the responsiveness of this aging but vital surge sealift asset.

E. SUMMARY

In analyzing the Southwest Asia scenario, defense planners allowed three weeks for the arrival of the initial heavy combat forces and eight weeks for five fully equipped divisions. One month into Desert Shield, only the Marines and one light army division were in position. [Ref. 7:p. 1]

Desert Shield confirmed that the U.S. force structure, designed for a European war versus the Soviet Union, lacked the mobility necessary to promptly respond to diverse regional threats. We still do not have the capability to deliver a heavy division and much of its combat support equipment within three weeks. If private U.S. flag ships are not promptly requisitioned, and if sealift assets are as sluggish to

activate as during Operation Desert Shield, delivery of major combat and support forces will arrive between two and five weeks late. [Ref. 7:p. 5]

Our nation had difficulties moving equipment in a combat-free environment, even with outstanding host nation support and tremendous access to foreign commercial vessels. Initial movements of personnel and material to the battlefield are of the utmost importance. It is clear that the time has come for the United States to aggressively enhance its ability to rapidly move troops and equipment into distant theaters.

III. WINGSHIP BACKGROUND

A. AERODYNAMICS

As a general rule, the aerodynamic efficiency of conventional airplanes increases as the wing span for the required wing area increases. The length of the wings is primarily restricted by the stresses exhibited at the juncture with the fuselage [Ref. 14:p. 3-1]. Without branching into new realms of technology, the advances in lift capability for cargo transports will be limited. The C-17 Starlifter, the transport aircraft currently being built by McDonnell Douglas, has been plagued with setbacks including the resolution of stresses related to the length of the wings [Ref. 15]. The wingship provides a tremendous increase in lift over current cargo aircraft despite its short and stubby wings. By exploiting ground-effect, these aerodynamic ships achieve lift that is not possible in platforms where lift arises from wing length. Table III shows the cargo carrying capacity of current air assets and the wingship [Ref. 3].

TABLE III
THE WINGSHIP VERSUS AIR TRANSPORTS

	PAYLOAD (TONS)	SPEED (KTS)	RANGE (NM)
C-5	121	450	5900
C-17	86	450	6300
WINGSHIP	1500	400	10000

The Wright brothers were perhaps the first to observe aerodynamic ground-effect. They noticed that their gliders covered the greatest distances when only a foot or so off the sand dunes of Kitty Hawk [Ref. 2:p. 4]. Because of the ground-effect phenomenon, it is technologically feasible to "build an aircraft three times larger and ten times heavier than the largest airplane currently manufactured or envisioned." [Ref. 14:p. 1-1]

B. CHARACTERISTICS

The vessel under analysis by ARPA is shown in Figure 2. Dimensions and characteristics of the 5000-ton wingship are shown in Table IV [Ref. 14:p. 2-12].

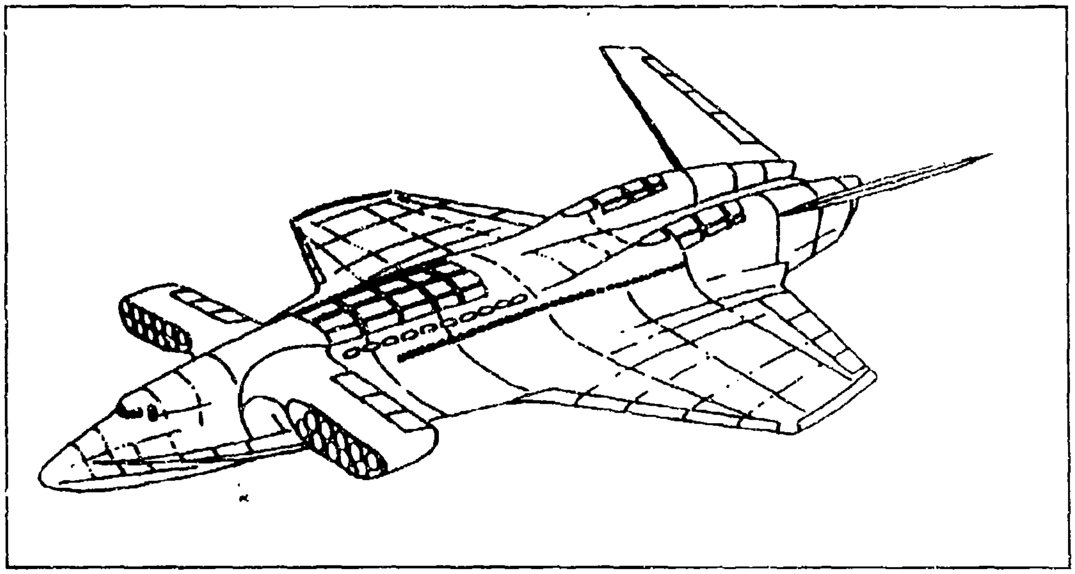

Figure 2. The 5000-Ton Wingship

TABLE IV
WINGSHIP CHARACTERISTICS

WEIGHTS (short tons)			
Maximum Gross Take-off	5150		
Maximum Aft Cargo	1200		
Maximum Forward Cargo	350		
Maximum Fuel	2250		
EXTERNAL DIMENSIONS (feet)			
Height Overall	115		
Length Overall	550		
Fuselage Length	507		
Fuselage Depth (max)	62		
Wingspan	340		
INTERNAL DIMENSIONS (feet)			
Aft Cargo Bay		Deck Areas (approximate)	
Length	225	A-Deck	19,000
Height	23	B-Deck	27,000
Width	50	C-Deck	23,000
		D-Deck	11,700
		E-Deck	12,800
		F-Deck	2,500

C. OPERATIONS

The four primary modes of wingship operations are depicted in Figure 3 [Ref. 3]. When waterborne in the sea-sitting mode, the craft operates much like a traditional ship. The ship maneuvers with two after-mounted screws and one forward-mounted unit. Three different modes of displacement propulsion are under investigation. All modes involve retractable propulsion gear that is driven by reliable diesel engines. Speeds may be limited to ten knots and maneuverability much as it would be for conventional waterborne vessels of comparable size. The small draft of the wingship, less than ten feet when fully loaded, gives the craft an advantage over deep-draft vessels that may be unable to enter shallow ports. [Ref. 16]

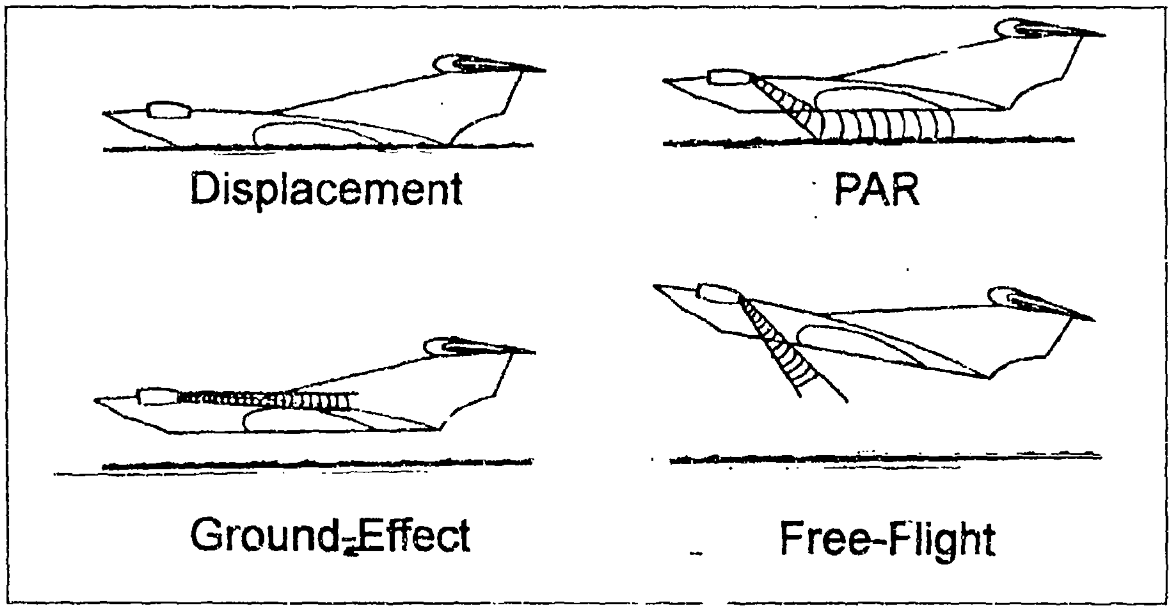

Figure 3. Wingship Modes of Operation

Wingships operate in the Power Augmented Ram (PAR) mode during takeoff and landing. Because of the greater induced drag while moving into and out of the water, additional thrust is required. On takeoff, for example, jets positioned on the forward part of the aircraft vector thrust under the leading edge of the wing until the aircraft is clear of the water and can utilize ground-effect. Speeds may be limited to 150 knots while strictly in the PAR mode of operation.

The most efficient mode of operation is the surface or ground-effect mode. The wingship flies between 20 and 90 feet above the surface of the water. The smaller the craft, the lower the vehicle must fly to optimize ground-effect. In ground-effect operations, the aft-mounted cruise engines are operating, and the forward-mounted engines are shut down or operating at reduced power. Speeds up to 400 knots are possible.

Conventional aircraft flight or "free air operation" is used when operating out of ground-effect at a high angle of attack. Wingships will transit to "free air operation" to fly over small land masses or canals, or to avoid shipping and other obstacles in the normal flight path. This mode of operation requires maximum power and is fairly inefficient. [Ref. 17] Even under these less efficient conditions, speeds of up to 350 knots are possible [Ref. 18].

The wingships were originally designed as RO/RO platforms with the added capability to transport commercial containers,

bulk dry goods and troops. Wingships using the same pier facilities as traditional sealift assets will be able to load military vehicles at approximately the same rate [Ref. 19]. The wingship can also accommodate outsize equipment not easily transportable aboard military aircraft. As with normal aircraft loading, some cargo types will be weight-limited and other loads will be area-limited.

Special cranes have been designed to load containers into the wingship. However, containers routinely drop during loading operations. The danger of a dropped load and the certain devastating effect on the airframe make this mode of operation less likely than previously envisioned. Movement of dry cargo is much more profitable on ships, so this method of transport will be used only in rare occasions. [Ref. 19]

After loading, wingships will transit in the displacement mode until clear of other shipping and obstacles. The ship will then transition to the PAR mode of operation and then rapidly into ground effect. Wingships will fly in ground-effect along the same routes used by other sealift assets. Upon reaching a strait or other navigational chokepoint, wingships will transition to the less efficient free-flight mode. Once clear of dense shipping, the vehicle will return to ground-effect, its most efficient mode of operation.

D. POTENTIAL MILITARY UTILIZATION

Wingships have the capability to discharge their cargo at developed or undeveloped ports. Delivery of goods to established port facilities is the primary mode of operation. Cargo offload of the wingship will occur at approximately the same rate as offload for similar cargo from traditional ships. Offload of a fully loaded wingship requires eight to twelve hours if discharging RO/RO or container loads.

If delivering goods to an undeveloped port, the vehicle can beach itself and utilize the bow ramp to offload self-propelled equipment. The vehicle can also operate in the PAR mode of operation to maneuver to an optimal delivery point farther up the beach. If the load is not self-propelled, the entire lower deck of the wingship may be moved onto the beach in approximately two hours by utilizing jupes. Jupes are round cavities fed with low pressure air that provide a means to float the lower deck out of the vehicle [Ref. 20]. The deck will move on a cushion of air much like a puck in an air hockey game. Not all beaches are suitable for offload of equipment. If there is not adequate access to major roadways or railways from the offload point, the gear may be stuck on the beach.

Wingships designed for amphibious operations must withstand additional stresses due to pounding waves and landings ashore. Because of the structural enhancements required for these amphibious wingships, the lift capability

is necessarily lower. A wingship landing at an undeveloped site can transport a load approximately two-thirds the size of a load carried by a wingship designed to offload at established ports. [Ref. 19]

The wingship has fuel tanks in the wings and the fuselage. Refuelings of wingships will be conducted in port during cargo operations or at sea by an oiler. Mid-air refueling is not an option. In instances where fuel supplies are not readily available, such as initial landings at undeveloped ports, mid-mission refuelings will be conducted. A vehicle flying to the Persian Gulf, for instance, will top off in Italy on the inbound and outbound legs of the journey. This minimizes the time the asset is in theater prior to substantial combat forces being assembled.

A wingship fleet may be employed in the following manner: approximately ten will be used on a day-to-day basis by the military. Of those ten, one or two on each coast will be marked for a one-day turnaround dedicated to a military mission. Ten more wingships will be under TRANSCOM control and available for loading within two days. The remaining wingships will be in commercial use. If needed for a military mission, they will be called up much like airliners under the Civilian Reserve Air Fleet (CRAF) and will be available for loading within five days. [Ref. 19]

IV. MODEL DESCRIPTION

A. SEALIFT PARAMETRIC ANALYSIS MODEL

As stated in Chapter I, SPAM was utilized to determine the impact of wingships on strategic lift. Built as a result of congressional action in fiscal year 1990 legislation, SPAM was designed to "compare the relative value of technology combinations" in traditional sealift ships [Ref. 21:p. 3]. SPAM is an event stepped Monte Carlo simulation written in the SIMSCRIPT II.5 language. The model computes the amount of cargo delivered over a selected time period for a chosen combination of sealift ships, routes, and ports. The model generates graphs of cargo delivery versus time, an event-by-event chronology, and summary statistics. The summary statistics contain 95 percent confidence intervals for the mean tonnage and mean square footage delivered, and the average and maximum number of ships waiting to be loaded or unloaded at each port of embarkation or debarkation, respectively.

Because of the complexity of deriving an analytical model to completely describe our nation's sealift, simulation is a practical means to obtain useful data about various asset mixes. In particular, a Monte Carlo simulation is defined as "... a scheme employing random numbers, that is, uniform(0,1)

random variates, for solving certain stochastic or deterministic problems.... " [Ref. 22:p. 113]

SIMSCRIPT II.5 is a specially designed simulation language. Simulation models built in SIMSCRIPT II.5 are significantly smaller than those built using a general purpose language like FORTRAN, Pascal, or C. Fifteen thousand lines of FORTRAN code would be needed to create a model equivalent to the four-thousand line SPAM written in SIMSCRIPT II.5 [Ref. 21:p. 5]. Execution times are also shortened by using a simulation-specific language.

SPAM output was corroborated during Desert Shield. There was good correlation between the actual delivery rates for sealift vessels during the buildup for the Persian Gulf War and the SPAM-generated output. [Ref. 23]

The following information is required for each of the sealift assets in the user-generated input data set: ship type (RO/RO, container, bulk, or tanker), initial location, readiness state, cruising speed, unrefueled range, capacity, stow factor, load and unload times, number of shafts, mean time between propulsion or mission-aborting failures, mean time to repair, and probability of loss due to air, submarine, or mine threat.

Necessary port information in the input data set includes the following: number of berths, probability of being

attacked, probability of attack survival, capability to load and unload ships, location of repair and refueling facilities, and delay times.

Information about routes in the input data set includes the seaports of embarkation (SPOE) and debarkation (SPOD), distance between ports, threat probabilities along the route, probability the route is utilized, refueling delays, and applicable canal transit delays.

The following assumptions are implicit to the model:

- Refueling assets are available when needed during transit.
- Prepositioned assets are at their forward locations and are immediately sent to their POD.
- Ships unable to utilize a home or foreign port because of damage proceed to the next closest facility for loading or unloading.
- Goods are ready to be loaded or offloaded as soon as ships moor.
- Ships require six hours to transit into or out of port.
- There are no restrictions on port entry times or cargo load and unload times. Tugs, pilot services, and other support are available for around-the-clock operations at port facilities.
- Maintenance is conducted while vessels are in transit.

B. IMPACT OF IMPLICIT ASSUMPTIONS ON MODEL OUTPUT

Having prepositioned assets at their forward locations optimistically predicts MPS performance. During Desert

Shield, one of the MPS vessels normally forward-based in Diego Garcia was undergoing overhaul in the United States. This vessel delivered her cargo three weeks after initial deliveries by other ships in the squadron [Ref. 5:p. B-11].

The model is restricted to modeling the movement of shipping between ports. Delays on the ground due to late cargo arrival are not modeled specifically. Random delays are modeled, but they do not accurately represent the load delays experienced by sealift vessels in Operation Desert Shield. This delay is time dependent. During the surge phase of the build-up for the Gulf War, cargo was available for loading 70 percent of the time when ships were ready for loadout. During the sustainment phase of the Gulf War, cargo was ready to be loaded just 34 percent of the time when ships arrived. [Ref. 5:p. 16]. Since the wingships make more deliveries, their performance is more grossly modeled.

The transit times for vessels account for delays due to tidal variations, navigational chokepoints, and possible mine threats. A six-hour transit for vessels outbound from POEs or inbound to PODs is reasonable for ships but too conservative for the wingship since it operates in the displacement mode for only a limited time.

The lack of restrictions on port entry times in the model has little effect on the output of the model. It is

reasonable to assume that ports will operate on a twenty-four hour basis during mobilization.

For sealift vessels, routine maintenance may be performed during transit or may be deferred until the next scheduled shipyard availability. It is realistic for conventional ships to complete multiple deliveries without a break in operations. Maintenance for the wingship, as for cargo aircraft, must be completed more regularly. Traditional cargo aircraft have a down-time immediately following operations. For the 100 days of the analysis, traditional sealift vessels make a maximum of four round-trips. Wingships, on the other hand, may complete ten round trips during the surge phase of the operation. The wingship has 20 engines operating in a harsh seawater environment; a maintenance down-time must be simulated for the wingship if the results are to be realistic. Otherwise, the performance of the wingship is overstated.

Wingships may occupy more than one berth due to wings extending out over the pier. Wingship performance may be over estimated if a limited number of berths are equipped to offload wingships.

Individual ships traveled between multiple ports during Operation Desert Shield, but this cannot be modeled by SPAM. This restriction has little effect on the model output.

C. MODIFICATIONS TO SPAM

The original model was written to allow ships to be placed into one of four readiness states: ready, 10-day, 60-day, or build-and-charter. Since surge capability was specifically analyzed, several modules of the model were modified to delete the 60-day readiness category and include the option of the 4-day readiness category. The distribution of activation times for the 4-day vessels is uniform(0,4) days. An activation event for wingships was added to the model; activation times for these assets are uniform(1,3) days.

Many of the parameters for the wingship were difficult to determine. Since no wingships of such large scale have yet been constructed, much of the input data was design data. Where possible, data from related operating systems was researched to determine field-tested values. For instance, the refueling time for the wingship was determined by dividing fuel capacity by the normal pumping rate of an oiler. An additional two hours was added to the event time to allow for travel off the normal shipping route and hookup time.

Further changes to the original model were made to properly model wingships. The hybrid craft do not need to transit the entire inbound and outbound q-routes at either end of the open ocean transit. Q-routes define safe passage for ships into or out of port. Modules were changed to schedule

the open ocean transit one hour following the loading or unloading of the wingship. The one-hour delay was introduced to account for the time the wingship operates at lower than optimal speed in the displacement and PAR modes of operation.

Changes were also made to the event modules for canal transit. Passage times in SPAM for sealift vessels transitting the Suez Canal are uniformly distributed between 0.48 and 0.58 days. The transit time for ships through the Panama Canal is deterministic and equals 8 hours. Since wingships transition to free flight to fly over small land masses, canal transit times for the wingships are greatly reduced. A speed of 350 knots was used to determine the appropriate modeling time for the wingship to transit the canals. Wingships commence free-flight operations ten miles before the canal and continue in the free-flight mode of operations until ten miles past the chokepoint.

Modifications were made to modules to schedule an additional event for the wingships. A three-day maintenance period following cargo delivery is simulated so that preventive maintenance on the 20 jet engines can be performed. The lengthy maintenance period is an extreme worst case. If actual maintenance time is shorter, the wingship output is pessimistically modeled.

Figure 4 is a simple schematic of the modified version of SPAM showing the event progression for wingships. The only difference between the event progression for wingships and conventional sealift assets is the maintenance event at the SPOE. Major events in the simulation and the associated delays are shown in Table V.

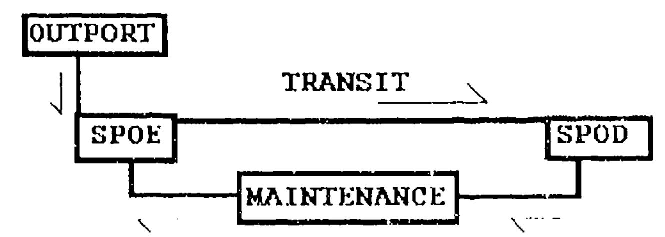

Figure 4. Modified SPAM Schematic

TABLE V
MAJOR EVENTS AND DELAY TIMES IN SPAM

OUTPORT	
ACTIVATION	WINGSHIP: U(1,3) DAYS RRF4: U(0,4) DAYS RRF10: U(5,10) DAYS FSS: U(0,4) DAYS MPF: NO DELAY APF: NO DELAY
SPOE (SPOD)	
CHANNEL TRANSIT	WINGSHIP: 1 HR SHIP: 6 HRS
LOADING (UNLOADING) LT = LOAD TIME	WINGSHIP: U(LT, LT + 2)HRS SHIP: U(LT, LT + 6) HRS
MOORING	WINGSHIP: U(0,3) HRS SHIP: U(0,3) HRS
MAINTENANCE	WINGSHIP: 3 DAYS (SPOE ONLY)
TRANSIT	
REFUELING	WINGSHIP: 4 HRS SHIP: SHIP DEPENDENT
CANAL TRANSIT	WINGSHIP: SUEZ - 15 MIN PANAMA - 8 MIN SHIP: SUEZ - U(.48,.58)DAYS PANAMA - 8 HRS

V. ANALYSIS

A. INTRODUCTION

Input files were created for two of the most difficult scenarios envisioned by defense planners. Conflict in Southwest Asia and buildup for a conflict in Korea with no aid from Japan were the test cases. Unsupported engagements in these arenas demand maximum use of strategic lift assets. Input data files were created for two situations in each theater. The asset mixes included 10, 20, 30, or 40 wingships and current and projected PREPO, MPS, and RRF inventories. The projected fleet levels are based on full implementation of the force levels recommended in the recently completed MRS. The goal of the model was to determine how much more quickly a notional deployment force could be armed and ready to fight with wingships in the strategic sealift inventory.

B. REQUIREMENTS ANALYSIS

1. Army Requirement

The Army Strategic Mobility Plan (ASMP) is a program to "deploy a CONUS-based five division contingency corps anywhere in the world." [Ref. 24:p. 1] This plan, a major factor in the recently completed MRS requires the deployment

of the following units: one airborne division, two heavy divisions, one air assault division, two heavy brigades, and the associated Combat Support (CS) and Combat Service Support (CSS) equipment. CS includes engineers, military intelligence, signal and chemical support. CSS includes transportation, ammunition, maintenance, quartermaster, and administration services. Without support, divisions are limited by fuel and ammunition and can fight for just three days. The amount of square footage of CS/CSS gear required to support each division is approximately two times the combat gear requirement. [Ref. 24:p. 2]

The unit movement requirements are included in Table VI [Ref. 25:p. 25]. The total entered in the sixth column of Table VI is the total square footage lift requirement for the unit and its necessary support equipment.

TABLE VI
UNIT MOVEMENT REQUIREMENTS

TYPE UNIT	# PERS	SQFT	STONS	MTONS	TOTAL
DIVISION					
Air Assault	16,170	996,781	32,546	168,594	2,990,343
Airborne	13,109	858,492	21,943	100,212	2,575,476
Armored	16,921	1,427,996	96,580	275,273	4,283,988
Infantry	16,938	1,169,664	59,508	210,006	3,508,992
Light Infantry	10,871	445,598	14,436	71,938	1,336,794
Mechanized	17,235	1,422,844	95,010	274,518	4,268,532
BRIGADE					
Armored	4,047	321,786	25,352	63,329	965,358

There are two different philosophies for the movement of CS/CSS gear. The first approach is to send combat cargo for the bulk of the divisions first, followed by support gear. This scheme was the option employed during Desert Shield. A better approach is to deliver support gear simultaneously with the combat gear for the division. Delivering combat gear and CS/CSS gear early provides the maximum strategic conventional deterrent and gives the divisions a rapid fighting capability.

Deployment of a five-division Army corps (a normal corps includes three divisions) per the ASMP including the following elements and associated support gear was analyzed: one airborne division, one air assault division, two armored divisions, and two armored brigades. The total lift requirement for the Army equals 16,064,511 square feet.

2. Marine Corps Requirement

Three Marine Expeditionary Brigades (MEBs) were simultaneously deployed to the theater of operations. It was assumed that the initial movements of cargo on the MPS assets fully supported the three forces. In addition, each Assault Follow-on Echelon needs 800,000 square feet of gear. The total Marine Corps requirement for the surge phase of any operation where three MEBs are deployed is 5,040,000 square feet.

3. Total Surge Lift Requirement

The total lift requirement is 21,104,511 square feet. Over the course of a entire war, sealift vessels historically carry 95 percent of all goods delivered into theater. Airlift assets transport proportionally larger amounts of equipment during the buildup than during the campaign. Assuming that ten percent of surge equipment will move by air initially, the sealift requirement for the notional deployment package is 90 percent of the total lift requirement or 18,994,059 square feet.

C. SPAM RUNS

Table VII shows the number and type of assets that comprise the current and projected strategic sealift forces. Selected inputs for the SPAM data sets are included in Table VIII.

TABLE VII
CURRENT AND PROJECTED SEALIFT FORCES

	CURRENT	PROJECTED
RRF	77	84
APF/MPS	21	30
FSS	8	8
LMSR	0	11
CHARTERS	15	10
TOTAL	121	143

TABLE VIII
SELECTED DATA INPUTS FOR SURGE ASSETS

	CAPACITY (KSQFT)	SPEED (KTS)	LOAD TIME (DAYS)
CURRENT ASSETS			
FSS	211	27.0	2.0
MPS	122 152	15.0 15.0	3.0 3.0
APF BREAKBULK	127	15.0	11.0
RRF RO/RO	86-220	15.2-22.5	0.5
RRF BREAKBULK	55-127	16.2-21.1	3.0
U.S. CHARTERS	166 220	15.0 15.0	3.0 3.0
PROJECTED ASSETS			
NEW APF RO/RO	300	24.0	2.0
NEW RRF RO/RO	150	18.5	0.5
LMSR	380	24.0	0.5
WINGSHIPS	97	400.0	0.4

The following assumptions were made to develop input data sets:

- Wingships perform to design specifications.
- All conventional surge assets and wingships have a stow factor, the ratio of square footage of cargo loaded to the square footage of deck space available, of 0.75.
- Wingships load only RO/RO or containerized cargo.
- Sealift asset activation times are as programmed.
- A limited number of U.S. charters will be available for surge support. These ships arrive at SPOE between ten and thirty days.

- There is no support from the international community for surge sealift assets.
- There is no threat to strategic lift assets in the vicinity of the SPOD.
- Only the delivery of dry cargo is considered.

D. IMPACT OF INPUT DATA SET ASSUMPTIONS ON MODEL OUTPUT

Assuming that the wingship performs to design specifications is indeed optimistic. The Aerocon-proposed design is still under investigation and will likely be modified. Since the 5000-ton wingship will be the first ground-effect vehicle of such large scale, there will undoubtedly be many alterations to the final production model. For example, the C-17 recently delivered to the Air Force had 125 waivers and deviations from the original contract specifications [Ref. 26].

For planning purposes, TRANSCOM uses a 0.75 stow factor for surge sealift assets [Ref. 24:p. 7]. In many cases, cargo loadouts for the wingship may be weight limited vice area-limited. In these instances, the stow factor of 0.75 is optimistic.

As discussed earlier, activation times for RRF vessels were abysmal during Operation Desert Shield. TRANSCOM's number one priority is the improved responsiveness of the surge fleet. The importance of sealift to our national defense was echoed when the defense budget was recently approved. A large amount of money was earmarked for sealift.

It is assumed that modifications to maintenance procedures will improve the responsiveness of these vessels. Also, it is expected that all eight of the FSSs will promptly deliver their cargo; one of the FSSs broke down during Desert Storm and made no deliveries to the Persian Gulf. Modeling RRF and FSS performance per Desert Shield might bias the analysis toward the wingships.

Lack of reliance on the international community for support is a conservative assumption. In some conflicts, there may be tremendous support, but the United States must be able to rapidly move its army without assistance. While foreign-flagged vessels delivered 28 percent of all dry cargo delivered to the Gulf over the course of the entire war, there was relatively little contribution from foreign-flagged vessels during the surge portion of Operation Desert Shield. No foreign charters arrived in theater by C+42; just 11 ships arrived by C+60 [Ref. 5].

"The validity of the cautious go-it-alone assumption with regard to foreign participation in U.S.-led military operations is punctuated by the lack of initial support from Japan and Germany." [Ref. 7:p. 1] These two nations depend more than the United States on oil exported from the Mideast, but provided no assets during the early phase of the buildup.

E. SPAM OUTPUT

1. South Korea Scenario

Figure 5 shows the cumulative square footage delivered to Pusan, South Korea by the current and projected sealift forces. The future force, enhanced with new RO/ROs, delivers five million more square feet by day C+60 than current assets. Ten million more square feet are delivered by day C+100. Assets begin to arrive in theater on day C+15 for either asset mix.

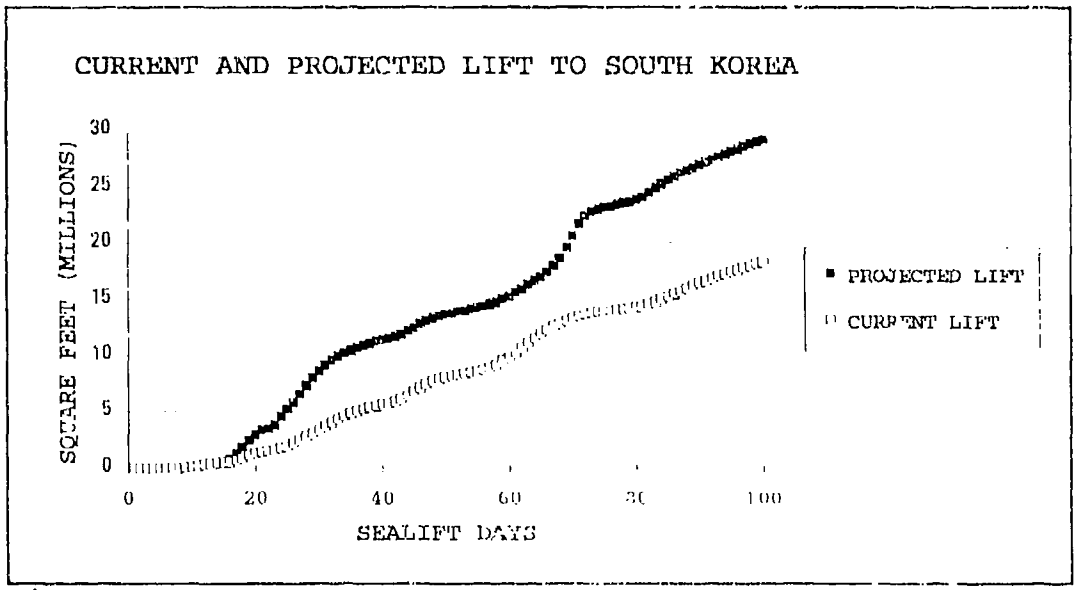

Figure 5.

Individual delivery profiles for fleets of wingships are compared with our nation's current surge capability in Figure 6. The terrific cargo delivery potential of wingships

is apparent. While a small fleet of wingships cannot match the equivalent square footage delivered by current sealift forces, the hybrid craft can quickly move tremendous amounts of cargo into theater. Early arrival of equipment in theater is terribly important to theater Commanders In Chief (CINCs). Having combat gear and defense systems in place immediately gives the CINC more defensive options and reduces the risk to troops already on the ground. The combination of speed and

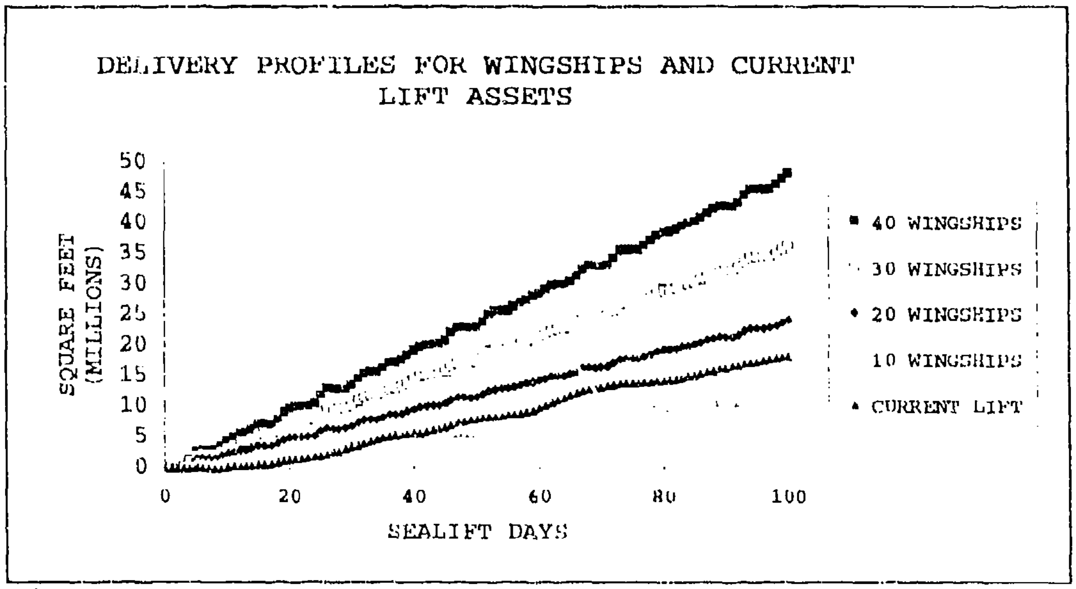

Figure 6.

cargo carrying capacity of the wingship is so great that just twenty wingships can deliver more cargo to Pusan than the current combination of strategic sealift assets. Twenty wingships can deliver over 24 million square feet of supplies to Pusan in a 100-day period.

Since wingships ideally augment, rather than compete with, conventional sealift forces, SPAM was run to model the

combined effect of wingships and sealift vessels. The amount of cargo delivered by wingships and the present and future sealift forces is shown in Figures 7 and 8, respectively.

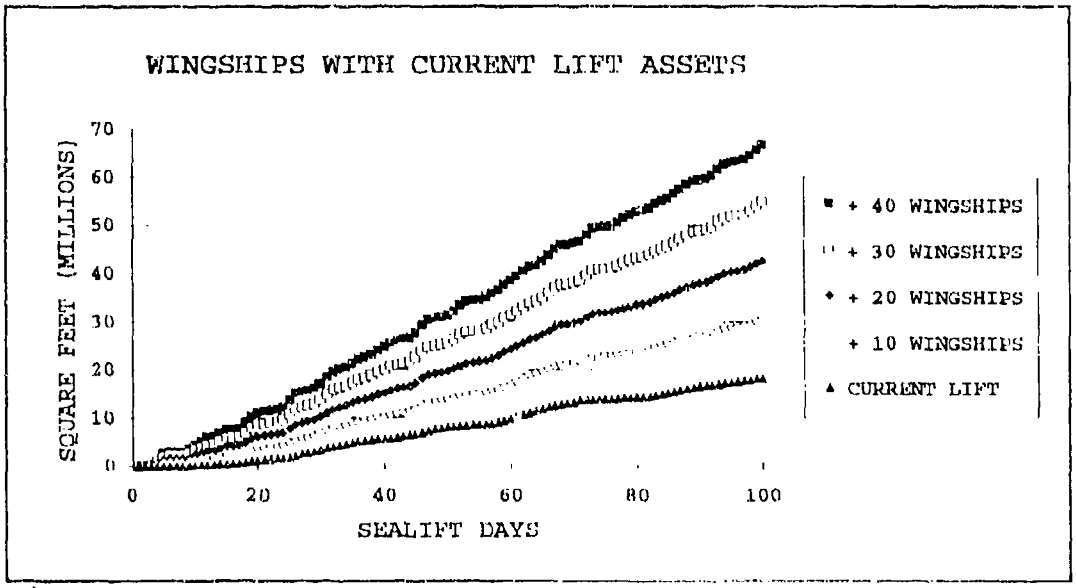

Figure 7.

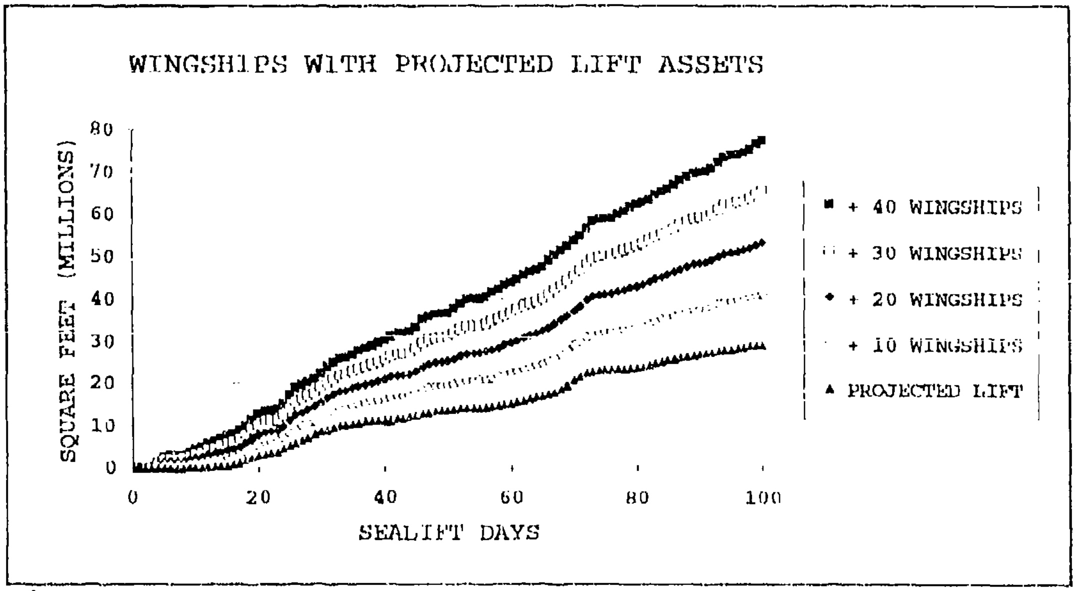

Figure 8.

Given the notional sealift cargo requirement of 18.9 million square feet to support five Army divisions and three MEBs, Figures 7 and 8 can be used to extract the force closure date for various combinations of wingships with current and projected strategic sealift forces. With current lift assets and no wingships, it takes 106 days to deliver the needed cargo into theater. Projected strategic sealift assets reduce the closure time considerably; the goal of 18.9 million square feet can be met in 69 days.

Figure 9 graphically depicts the change in force closure date for increasing numbers of wingships. Force closure improves considerably with employment of the first ten wingships, and improves at a noticeably decreasing rate as the inventory of wingships increases. It is noteworthy that the force closure date with future assets and no wingships, C+69, is nearly the same as the force closure date for the current lift assets and ten wingships, C+64. Similarly, future lift assets and ten wingships can deliver the same amount of cargo as current lift assets and 20 wingships by the same deadline, C+48. The improved lift capability of the future sealift force is roughly equivalent to the capability of a ten wingship fleet.

Figure 10 is an alternate presentation of the benefit realized for various numbers of wingships. Again, it is clear that the initial ten wingships have the greatest impact on force closure. When combined with current assets, ten

wingships reduce force closure by 42 days. Ten wingships reduce force closure by 21 days if combined with projected lift assets. Once the inventory of wingships reaches 30

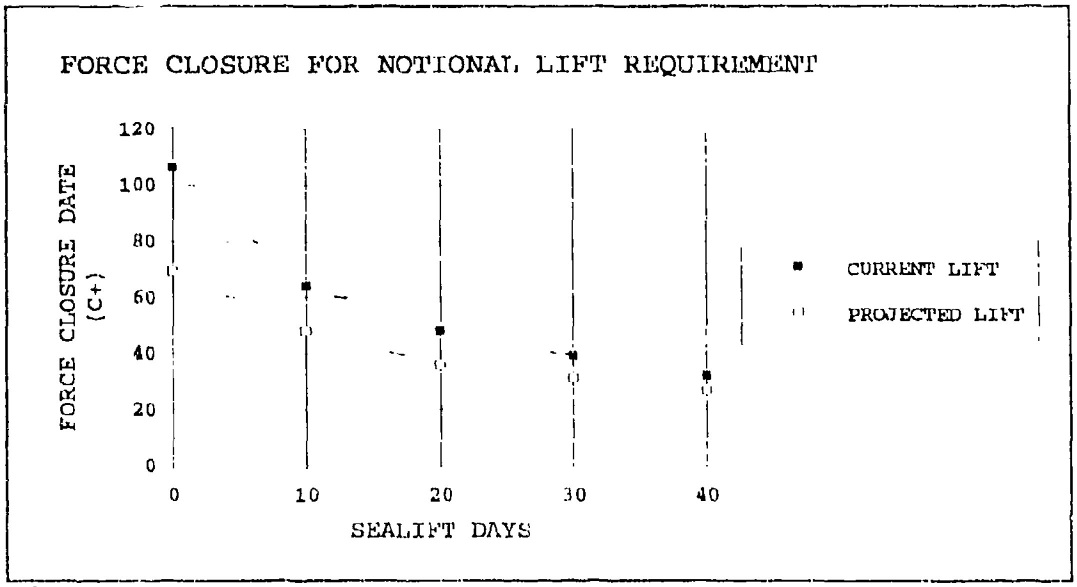

Figure 9.

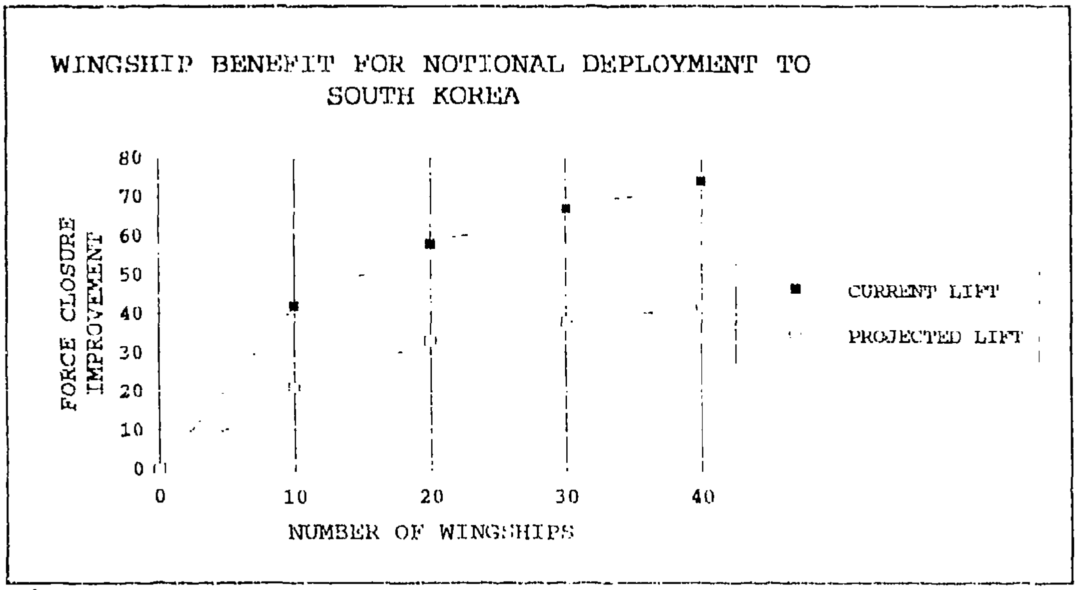

Figure 10.

ships, the marginal benefit of additional wingships is greatly reduced. With current lift assets, 40 wingships move the required load into theater one week sooner than a current fleet augmented with 30 wingships. As the wingship inventory is increased from 30 to 40 wingships, programmed sealift forces reach the target delivery goal just four days earlier.

The wingships modeled represent an active wingship force. If po -flight maintenance requires longer than the modeled three days, or if several craft are required to keep one wingship flying at such a high-cycle rate, the significant change in marginal benefit occurs at a proportionally higher inventory level.

The benefit of wingships is clearly dependent upon the amount of equipment that must be moved into the theater of operations. Sensitivity analysis was performed using lift requirements of 10, 15, 20, 25, and 30 million square feet. Figure 11 and Figure 12 show the reduction in force closure due to wingships with current and projected sealift forces, respectively. The benefit of wingships increases with an increasing lift requirement. If a 30 million square foot cargo requirement exists and current strategic forces are used, force closure is reduced by 12 days when the inventory of wingships increases from 30 to 40 vessels. Figure 11 shows that, independent of the lift requirement, it takes 30 additional wingships to match the equivalent force reduction of the initial ten wingships.

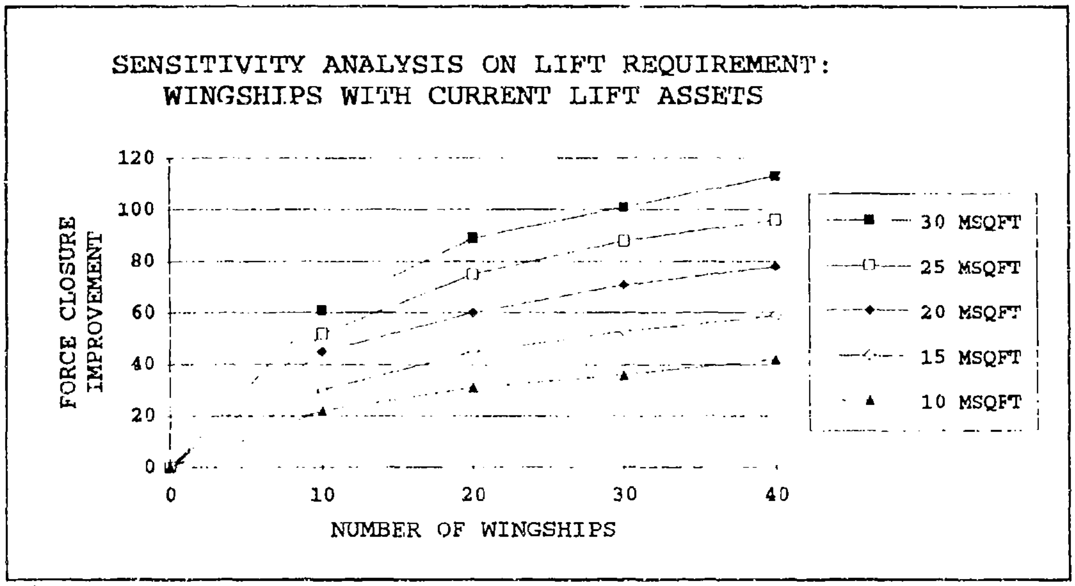

Figure 11.

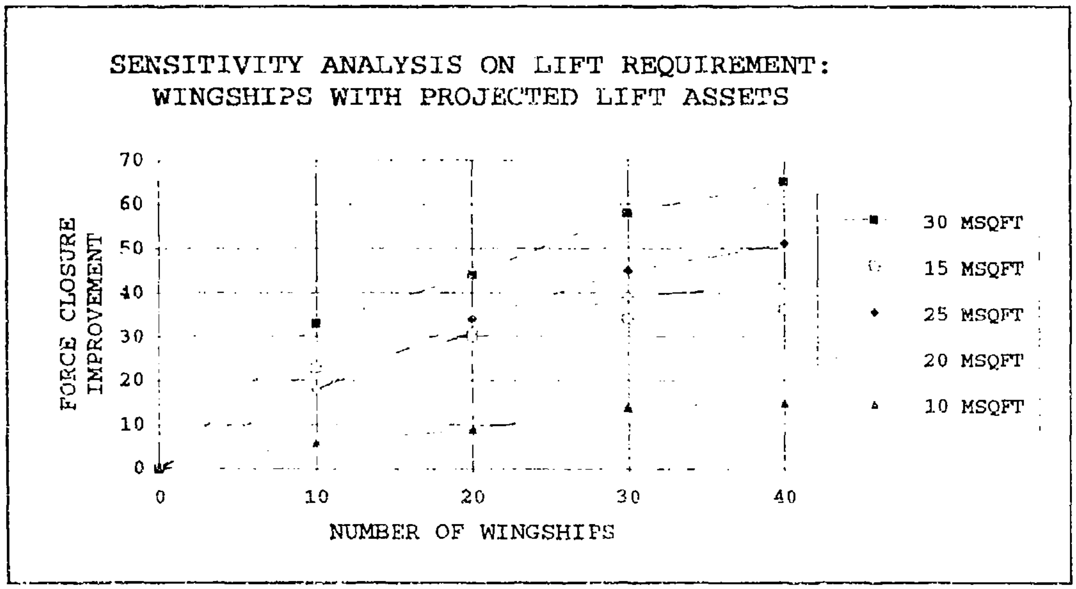

Figure 12.

From Figure 12 it is clear that wingships drastically improve force closure if the lift requirement exceeds ten million square feet. The force closure improvement is less predictable in this instance. The combination of the effects of the increased cargo capacity of the future sealift force and the cyclical nature of the cargo deliveries by the ships causes the curves to behave differently. The initial ten wingships reduce force closure more for a 15 million square foot requirement than the 20 million square foot requirement because the delivery rate of the wingships is relatively constant while the deliveries by the conventional surge assets is variable. The 15 million lift requirement is met with wingships while the delivery rate by ships is at a lull. Force closure improvement is relatively independent of medium range lift requirements with ten or 20 wingships. The step improvement in force closure when a 30 million square foot requirement exists is again a function of the long cycle times of slowly moving surge sealift assets. Wingships travel with smaller loads, but they can deliver their cargo prior to sealift assets completing another round trip.

The amount of berth space at the POD can also potentially affect the rate of cargo delivery. Sensitivity analysis was performed on the number of berths available in Pusan to determine if the assumption of 24 berths drastically affects the ability of traditional ships to efficiently deliver their cargo. Figure 13 shows the mean square footage

(in thousands) delivered over a 100-day period with varying numbers of berths. Figure 14 shows the maximum and average number of ships waiting to unload their cargo during the same period.

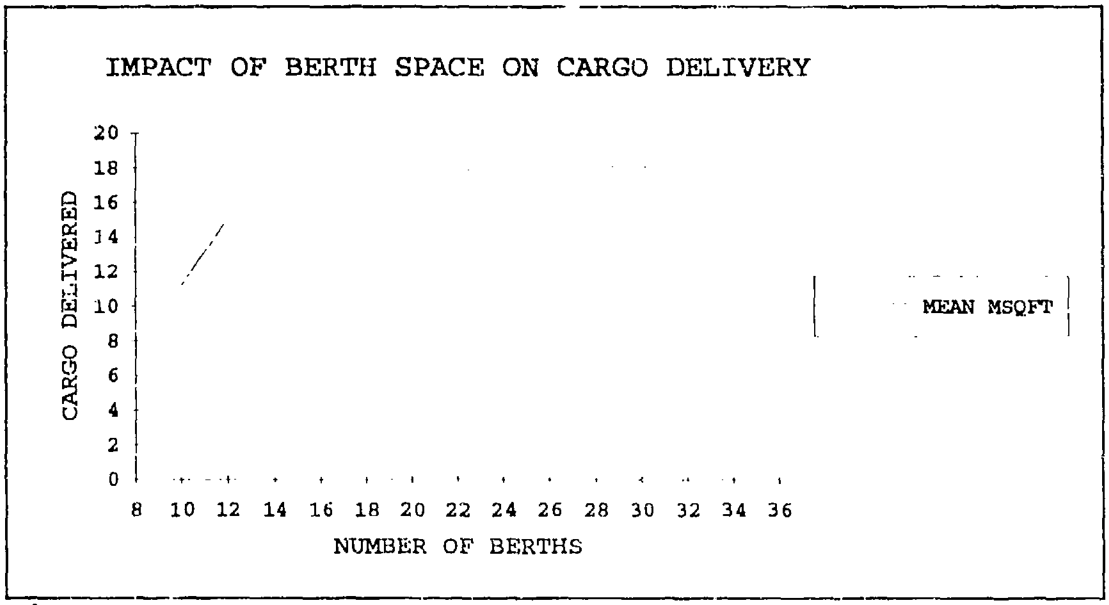

Figure 13.

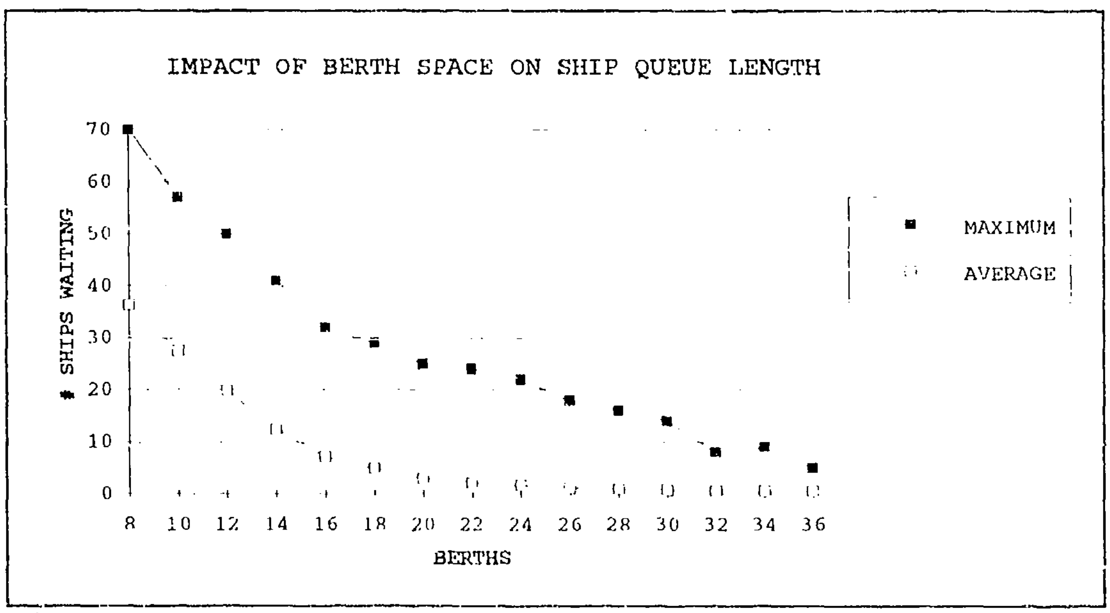

Figure 14.

With more than 14 berths, less ships enter a queue before unloading cargo. Clearly, the assumption of 24 berths does not significantly alter the results of the analysis if between 14 and 36 berths are available in Pusan for offload.

SPAM runs were also completed to perform sensitivity analysis on the wingship stow factor. The simulation was run for 60 days to assess the effect of a smaller stow factor on the quantity of cargo delivered. Over a 60-day period, ten wingships with a stow factor of 0.75 deliver three million square feet more than wingships with a stow factor of 0.45. The effect is linear; 40 wingships with a stow factor of 0.75 deliver 12 million more square feet than ships with a stow factor of 0.45 over the same two-month period.

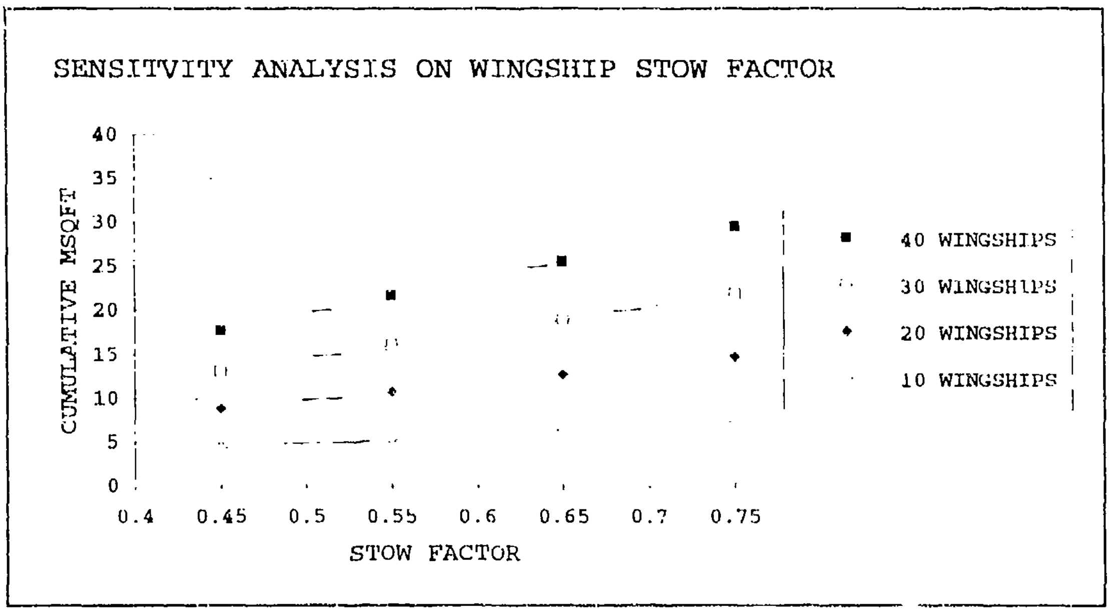

Figure 15.

To determine the change in force closure due to a smaller stow factor, the modified SPAM was again run for combinations of wingships and sealift assets. The requirement of 18.9 million square feet was held constant while the lift capability of the wingships was reduced. Figures 16 and 17 show the changes in force closure for 10, 20, 30, and 40 wingships augmenting current and future sealift force levels, respectively. Since wingships have a greater impact in a less robust sealift environment, lowering the wingship stow factor has a more pronounced effect in the case with current lift assets. Forty wingships with stow factors of 0.45 still deliver the required cargo into theater much sooner than pure sealift assets, but cargo arrives 13 days later than it would on wingships with stow factors of 0.75. If ten wingships are flying, gear arrives in theater nine days later on the more lightly loaded vessels.

In the case with projected lift assets, the largest change in force closure is evident if there are ten wingships in the sealift inventory. The ten wingships with a stow factor of 0.75 help improve force closure by 21 days. If ten wingships with stow factors of 0.75 augment sealift forces, force closure occurs just ten days sooner than it would without the wingships.

The stow factor is a driving factor in the number of wingships that should be acquired. For instance, from Figure 16, it is apparent that 30 wingships with stow factors of 0.55

provide the same force closure reduction as 40 wingships with stow factors of 0.45.

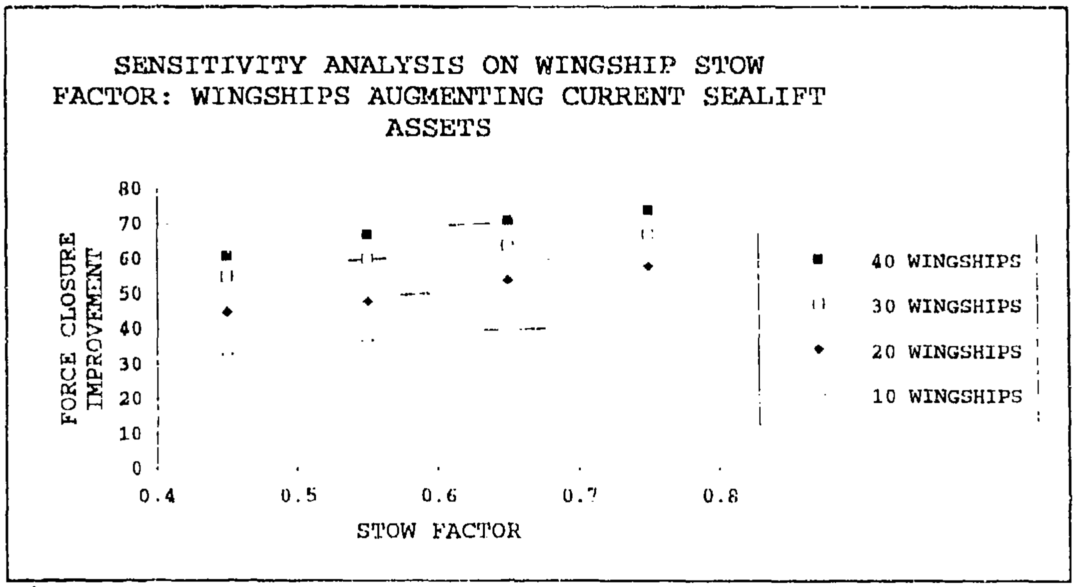

Figure 16.

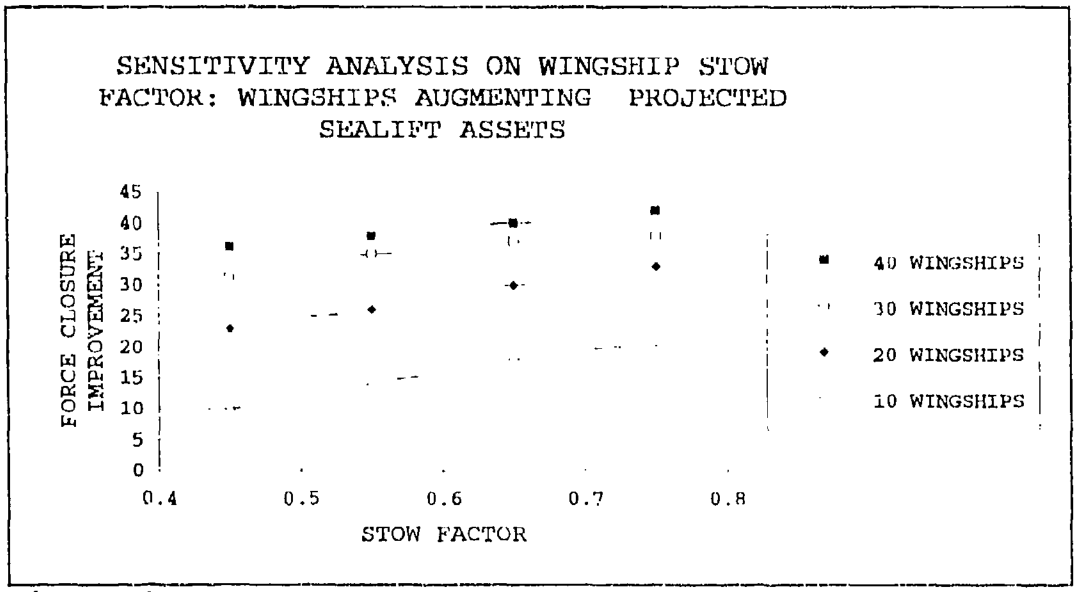

Figure 17.

Because of the delays in activating RRF vessels during Operation Desert Shield, sensitivity analysis was performed on the RRF break-out times. The distribution in SPAM for the activation event was modified to determine the effect on cargo deliveries by these ships. The original uniform(0,4) day activation was changed to a uniform(5,15) days and then to a gamma distribution. A normal distribution centered on the mean activation time could not be used since the data was skewed to the right. Also, the large amount of variance in the activation times caused negative numbers to be generated for the activation event, and the model abruptly stopped running. Figure 18 shows the delivery profiles for current RRF assets delivering cargo to South Korea. The difference in the amount of cargo delivered during a 100-day buildup is smaller than anticipated. Over the course of the build up, the maximum difference between the cargo delivered by the two forces with uniformly distributed break-out times is approximately two million square feet. It is important to note that the current RRF fleet consists of 77 vessels. Personnel and equipment were in short supply when just 44 RRF ships were activated during Desert Shield. It is unlikely that adequate support exists to activate all of the RRF assets on time.

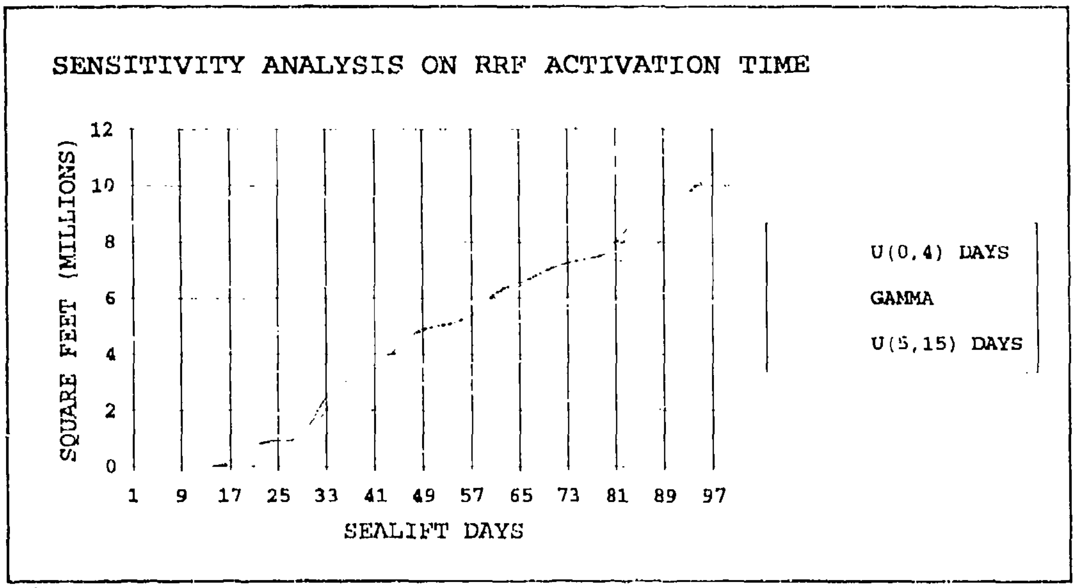

Figure 18.

2. Persian Gulf Scenario

Analysis was also performed to assess the impact of wingships on deployment to the Persian Gulf. The same numbers and type of assets are used to model the capabilities of the current and projected strategic sealift forces. Wingships and sealift vessels depart from both coasts of the United States and deliver cargo to two well-developed ports in Saudi Arabia. Ad Dammam has 30 berths for offload of material; Al Jubayl has 20.

Figure 19 shows the amount of cargo that can be delivered to the Persian Gulf using current and projected assets. With the enhanced surge sealift fleet, it is possible to deliver 14 million more square feet of cargo to the Persian Gulf than is currently possible. The projected sealift force

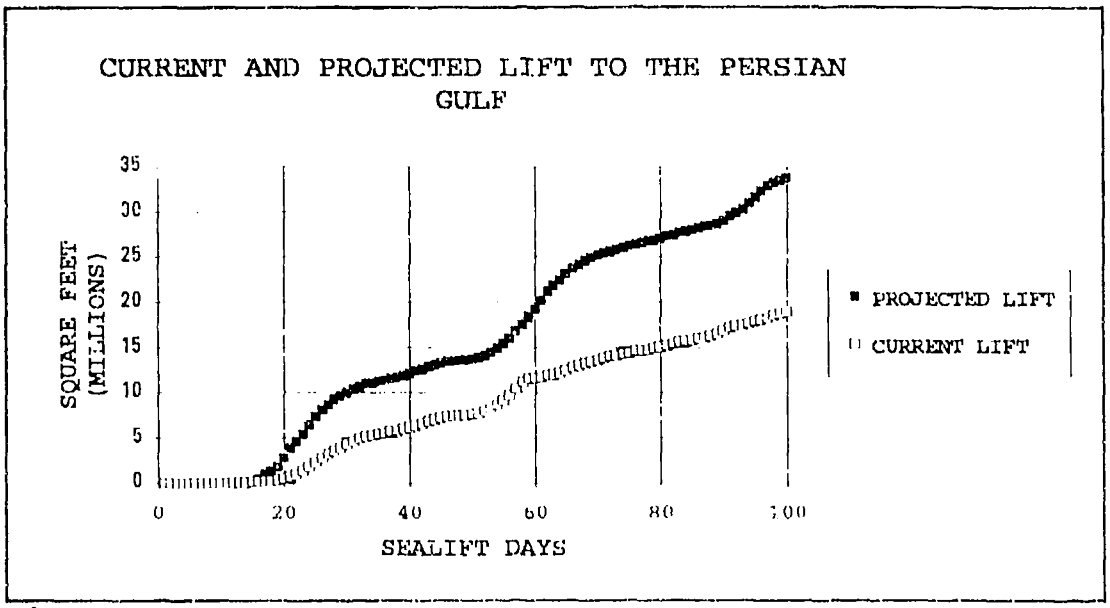

Figure 19.

can deliver 34 million square feet of cargo into theater over the 100-day period. This amount of cargo is approximately five million more square feet than could be delivered to South Korea over the same time period. The pronounced change in slope of the curve for projected lift assets is a function of the turn-around cycle for the new RO/ROs. The curve flattens out while the majority of the lift assets are completing their round-trip voyages.

Figures 20 and 21 show the cargo delivery profiles for wingship-augmented strategic sealift forces. These graphs differ only slightly from the graphs generated for deployment to South Korea.

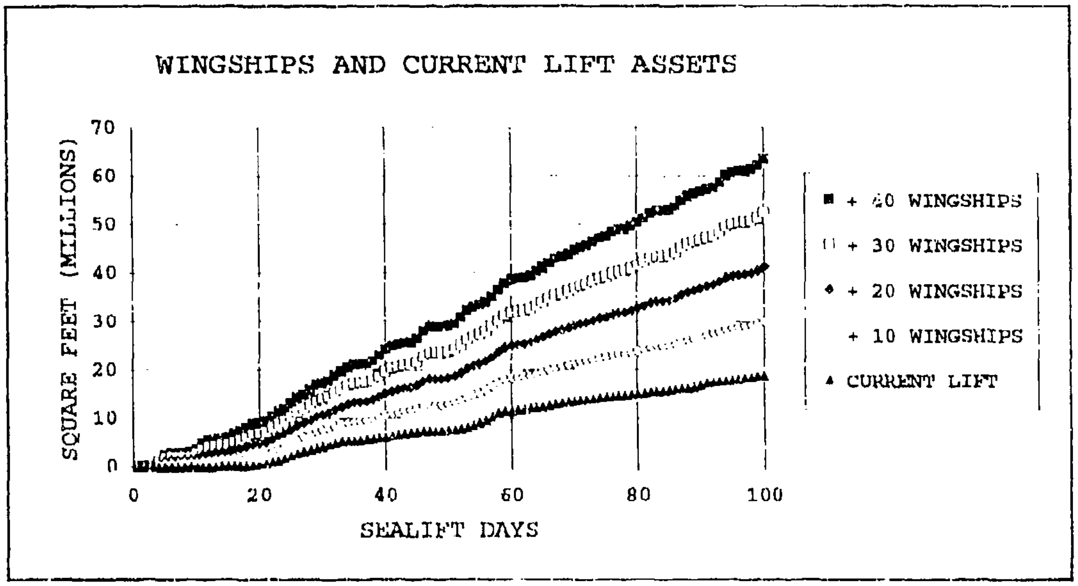

Figure 20.

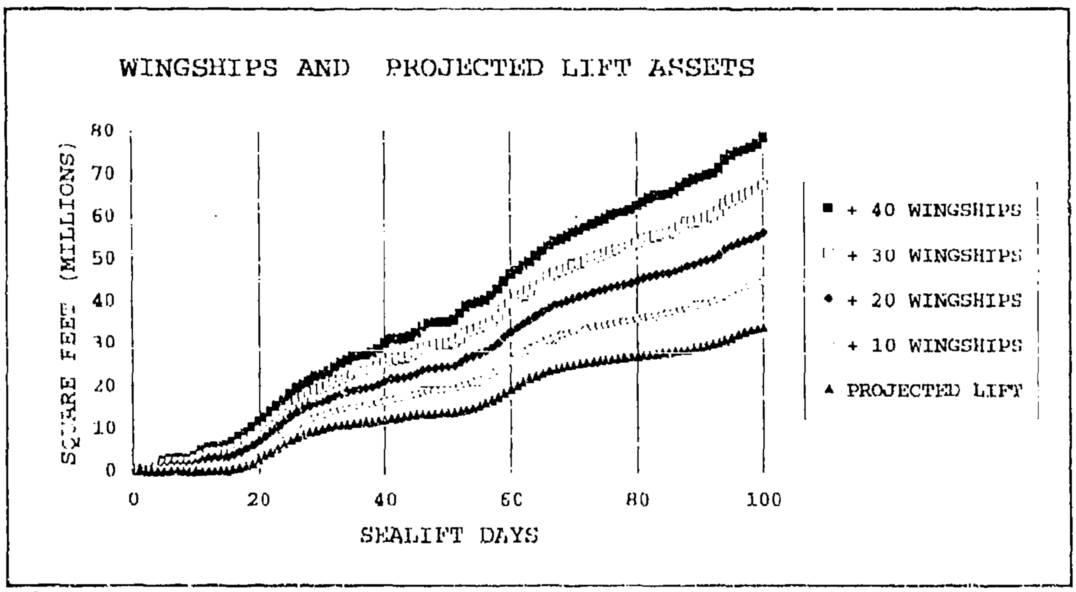

Figure 21.

The force closure curve generated for the 18.9 million square foot requirement for this scenario is shown in Figure 22. Once again, the force closure date can be reduced significantly by the first ten wingships. The benefit of acquiring more than 30 wingships is again small for both the current and projected lift cases.

Figure 23 shows the reduction in deployment time for various numbers of wingships. The shape of this curve is the same as for the deployment to South Korea, but the actual time savings is slightly different. It requires only ten less days to deploy the notional force to the Persian Gulf if ten wingships are employed with projected lift assets. If current lift assets are used, the build up period is shortened by 40 days.

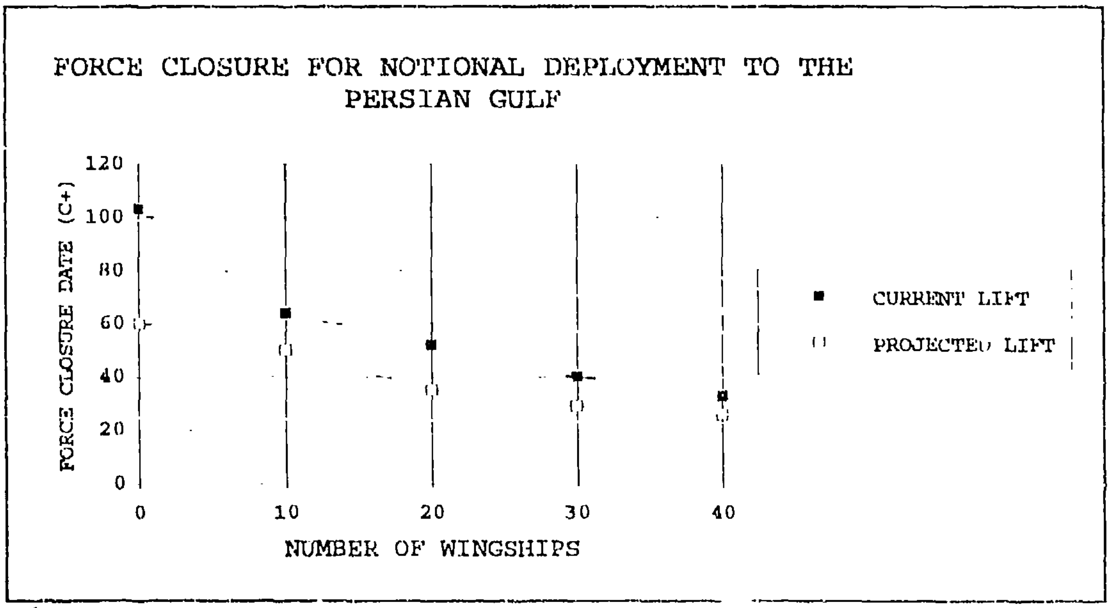

Figure 22.

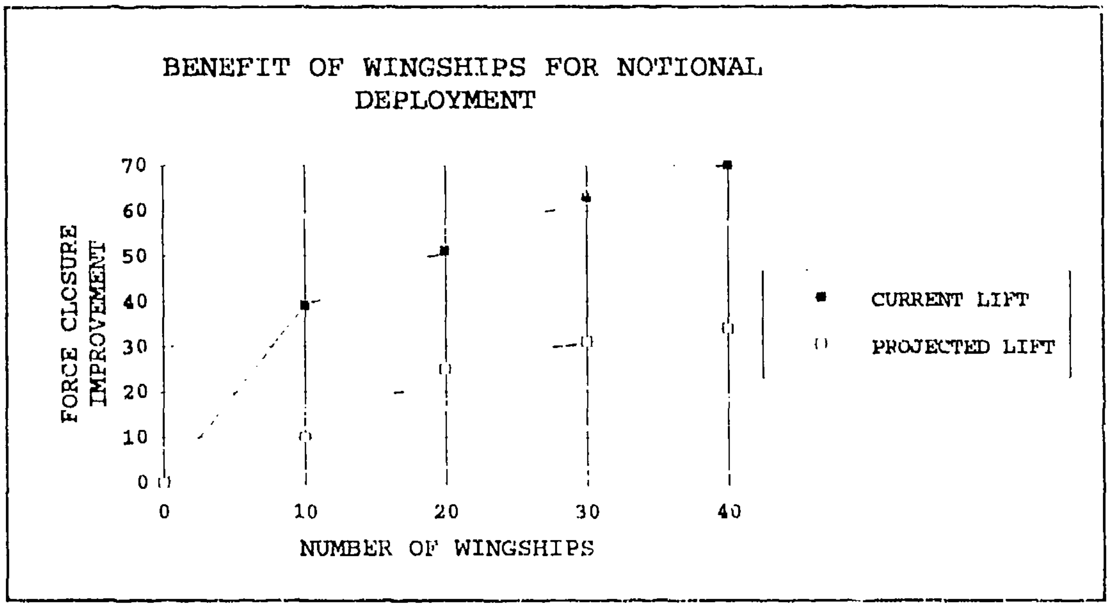

Figure 23.

As with the South Korea scenario, sensitivity analysis was performed on the lift requirement. Figures 24 and 25 show force closure reduction versus wingships for current and projected lift assets, respectively.

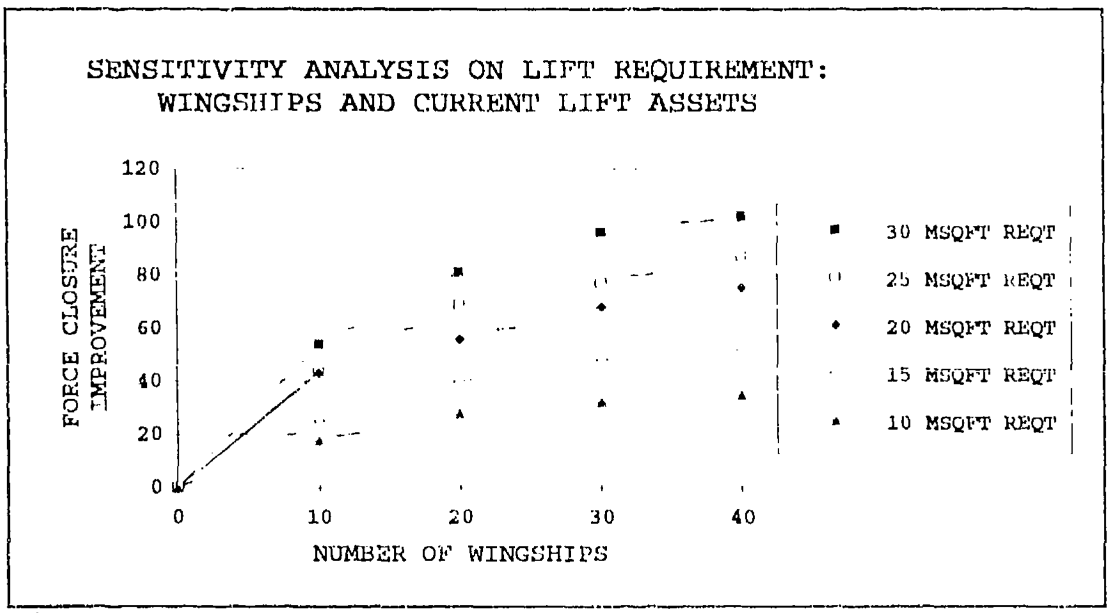

Figure 24.

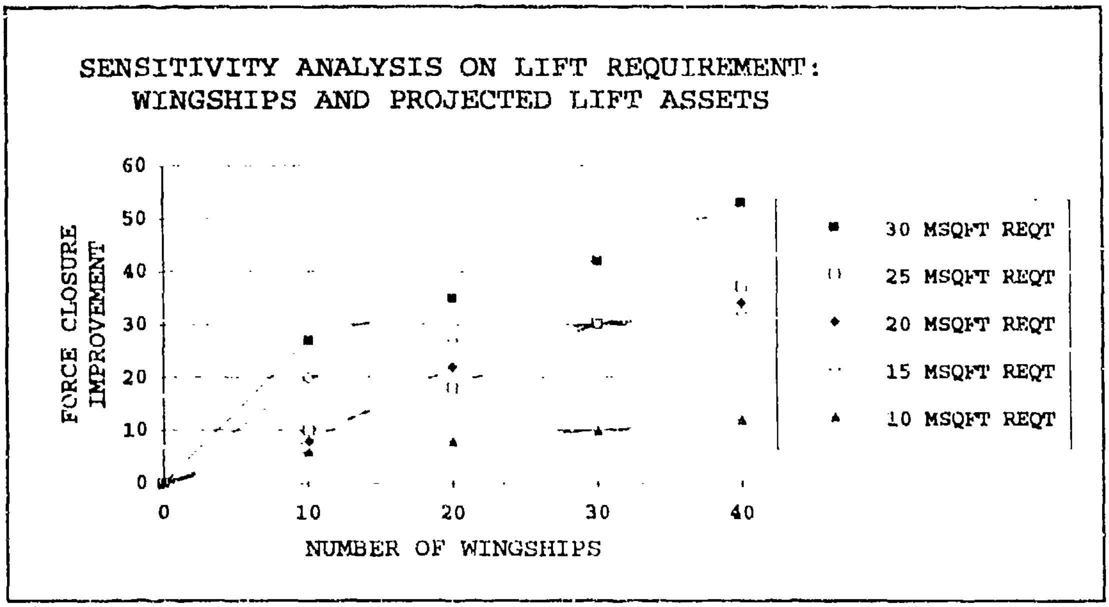

Figure 25.

Sensitivity analysis was performed on the number of berths available at Ad Dammam. Per the model, only prepositioned assets and wingships offload cargo in Al Jubayl, and there is adequate space to berth vessels destined for this port. Figure 26 shows the mean square footage of cargo delivered versus the number of berths utilized. The 95 percent upper and lower confidence intervals are also included on the graph. The amount of cargo that is moved into theater varies very little if at least 15 piers are available in Ad Dammam.

The maximum and average number of ships waiting to be offloaded is shown in Figure 27. If only ten berths are available for the duration of the buildup, a maximum of 52 ships will be in the queue, and the average number of ships in the queue for the 100-day scenario will be 22. The average

number of ships in the queue does not change appreciably if there are at least 15 piers and no more than 50.

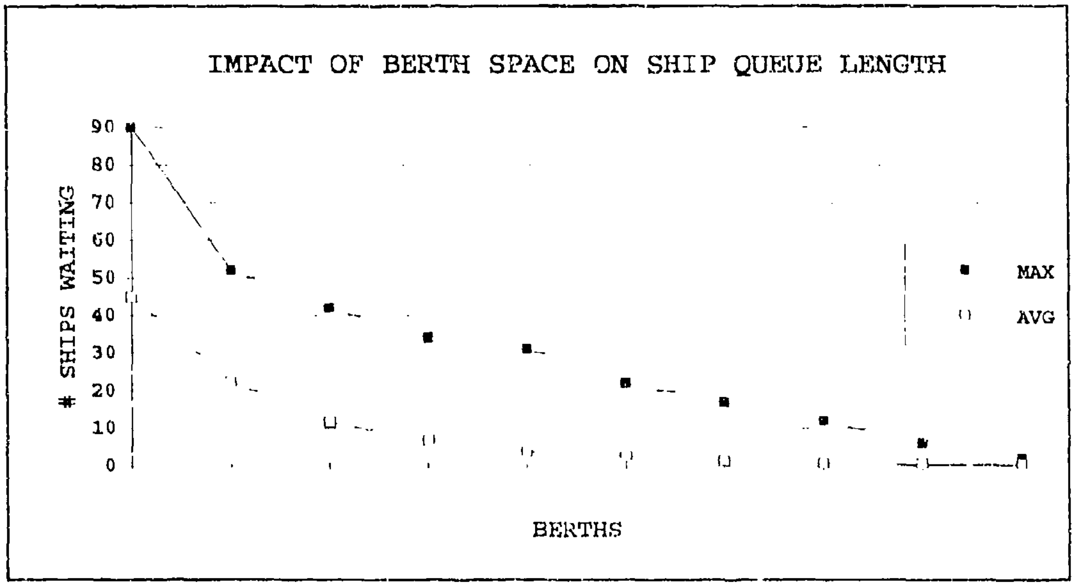

Figure 26.

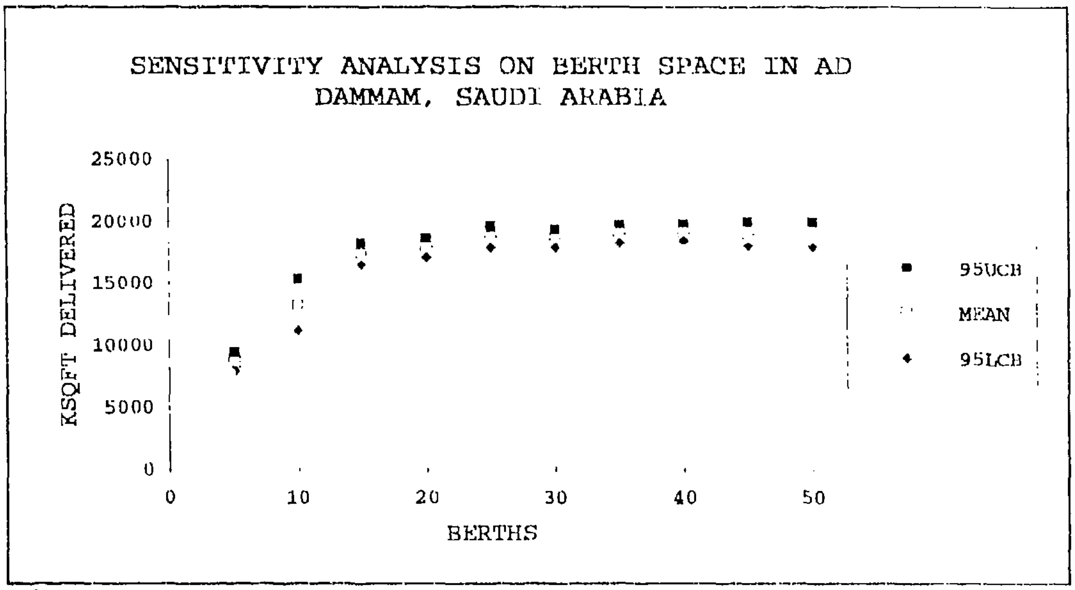

Figure 27.

Sensitivity analysis was again performed on the wingship stow factor to determine the impact on force closure. Figures 28 and 29 show how a changing stow factor affects the force closure improvement for the Persian Gulf scenario. the magnitude of change in force closure is smaller than in the South Korea scenario. The current strategic sealift force augmented with 40 wingships with stow factors of 0.45 deliver cargo just six days later than a same size fleet of wingships having stow factors of 0.75. Even wingships with stow factors with 0.45 drastically reduce the rate of force closure in both the South Korea and Persian Gulf scenarios.

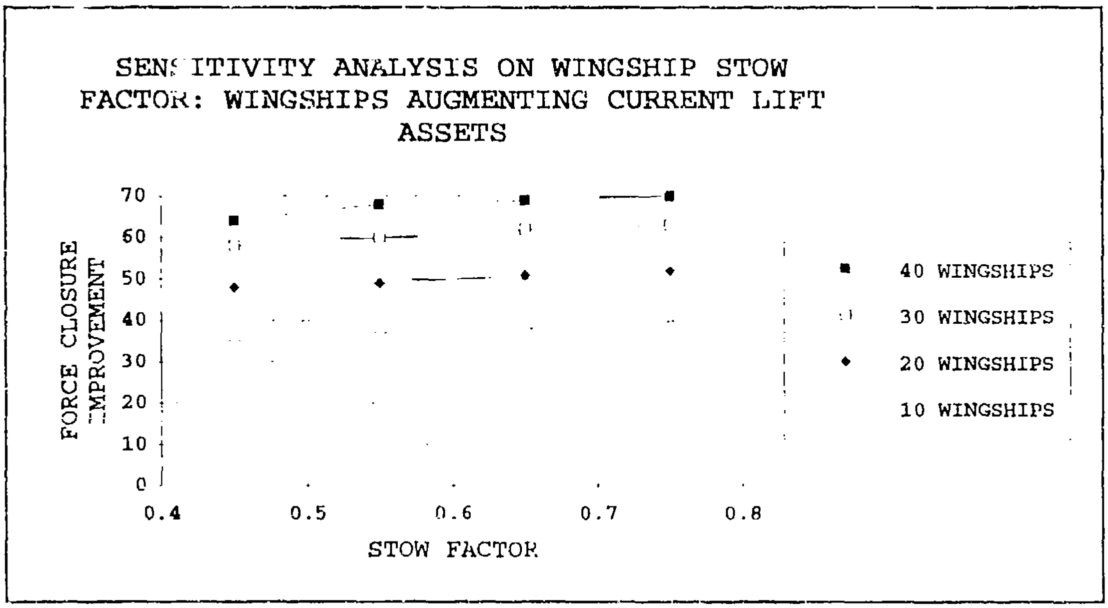

Figure 28.

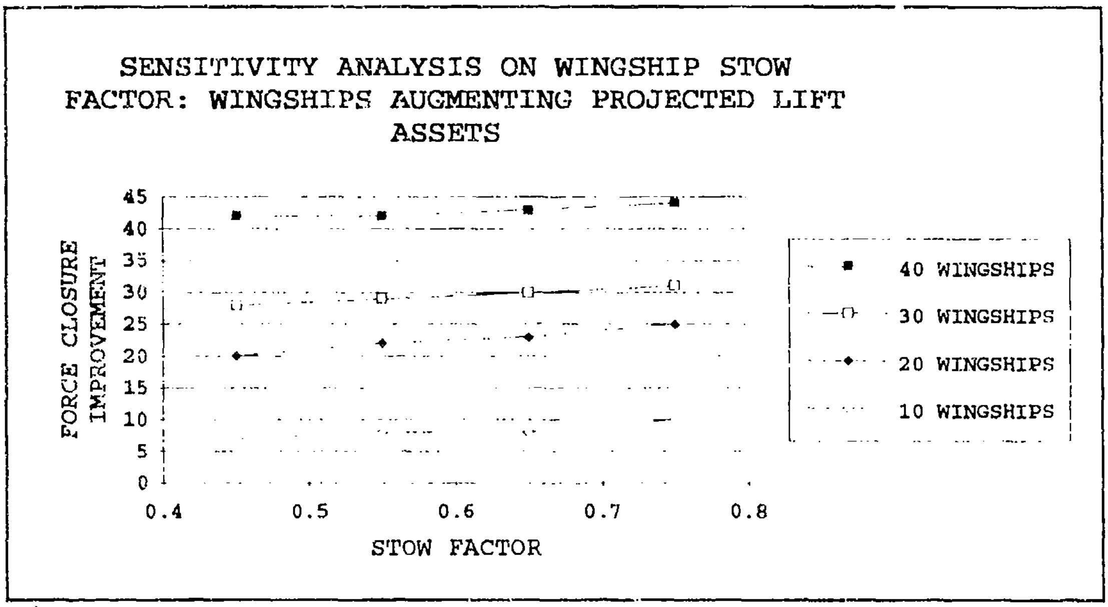
SENSITIVITY ANALYSIS ON WINGSHIP STOW FACTOR: WINGSHIPS AUGMENTING PROJECTED LIFT ASSETS
FORCE CLOSURE IMPROVEMENT
45
40
35
30
25
20
15
10
5
0
0.4
0.5
0.6
0.7
0.8
STOW FACTOR
40 WINGSHIPS
30 WINGSHIPS
20 WINGSHIPS
10 WINGSHIPS

Figure 29.

VI. CONCLUSIONS

The outputs of the original and modified SPAMs demonstrate that wingships can, without a doubt, drastically affect the rate at which fully-equipped forces can be delivered to distant theaters. If 40 wingships are used, a notional force requiring 18.9 million square feet of equipment can be deployed to the Persian Gulf or South Korea in approximately four weeks, two months sooner than is currently possible with sealift alone. Even if all programmed lift assets are acquired, a fleet of 40 wingships will still have a tremendous impact on force closure. Force closure for conflict in the Persian Gulf can be reached 34 days sooner if wingships are employed. Wingships reduce force closure to South Korea by 42 days if augmenting the projected sealift force.

The modified SPAM schedules round-trips for wingships flying between modern port facilities to Korea and the Persian Gulf in two to three days. The short turnaround time agrees with the expected performance advertised by Aerocon.

A. RECOMMENDATIONS

1. Enhancements to SPAM

SPAM is an excellent model for comparing the capabilities of different sealift forces. However, to permit

a more in-depth analysis of different asset mixes, the following two recommendations are made:

a - Modify SPAM to permit the scheduling of voyages between multiple ports. Arrays of information for SPOE and SPOD for each of the vessels, or further entries in the input data set for subsequent deliveries, would better model actual ship operations. Entries for ports of subsequent deliveries would enable, for instance, a prepositioned ship that has just dropped off her cargo to proceed to Germany to pick up and deliver army equipment to the Persian Gulf prior to heading back to the United States. Few of the ships used in Desert Shield and Desert Storm operated between just two ports. The wingship, in particular, is a prime example of a type of vessel that could potentially travel between multiple ports.

b - Modify SPAM to allow for specific types and numbers of loading/unloading facilities at each of the ports. Because of the differences of cargo handling equipment and, in the case of RO/ROs the need for loading ramps, not all ships can offload at the same berths. In the present model, a separate port, say Pusan-RO/RO, needs to be included in the foreign port data set if a limited number of RO/RO berths are to be simulated. Otherwise, the RO/RO ship unloads at the first available berth. Because of related entries, the addition of another foreign port is much more cumbersome than the inclusion of more specific information about berth capacities at each of the ports.

2. Areas for Further Research

A cost-benefit analysis should be performed to determine the correct allocation of sealift funds. Much of the money currently earmarked for sealift may be better spent on this new mode of high-speed ocean transit. Commercial involvement in the wingship program, with a program similar to CRAF, will offset many of the development and operation costs, and must be considered.

B. SUMMARY

The value of the early arrival of equipment in wingships is difficult to quantify, but of extreme importance. Especially in instances where there is very little warning time, wingships provide a huge conventional deterrent to potential adversaries. Future countries contemplating attacks on our nation or our allies know that they cannot err like Sadaam Hussein. They know that they must attack swiftly before sufficient forces can mobilize to counter the threat. Wingships will undoubtedly give theater CINCs increased flexibility and fighting potential. Aggressors faced with a rapidly-growing U.S. force may be forced to delay or alter their plan of attack.

The current timeline for force deployment is lengthy; deployment of a sizeable force in two months is the goal. Desert Shield demonstrated that even this long time frame is optimistic for our current strategic sealift fleet. With

wingships, a new standard for force closure is possible. Wingships are indeed a huge part of the solution of our nation's long-standing sealift deficit and should be aggressively acquired.

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